Contents

1. Introduction

1.1 Automated Vehicles and Connected Vehicles

In the context of smart vehicles, rapid technological developments are occurring within two areas defined as Automated Vehicles (AVs) and Connected Vehicles (CVs) as indicated in Figure 1.1. While the development of CVs and AVs is occurring largely independently, convergence of the two areas will be required to achieve full vehicle automation in the future (Main Roads, 2015a).

AVs are vehicles where aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input (NHTSA, 2013). Vehicles that provide driver safety warnings only (for example forward crash warning) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide safety warnings involves varying degrees of automation (e.g. the necessary data is received and processed, and the warning is provided without any driver input) (Main Roads, 2015a).

Those vehicles, which are 'connected' but are not able to perform any aspect of a safety critical function without driver input, can be termed Connected Vehicles. In general the development and deployment of CVs precedes AVs, but they do overlap. The emergence of both AVs and CVs is recognised as a key driver for Main Roads' new corporate strategic direction 'Keeping WA Moving' (Main Roads, 2015b).

The emergence of both AVs and CVs is recognised as a key driver for Main Roads' new corporate strategic direction 'Keeping WA Moving'.

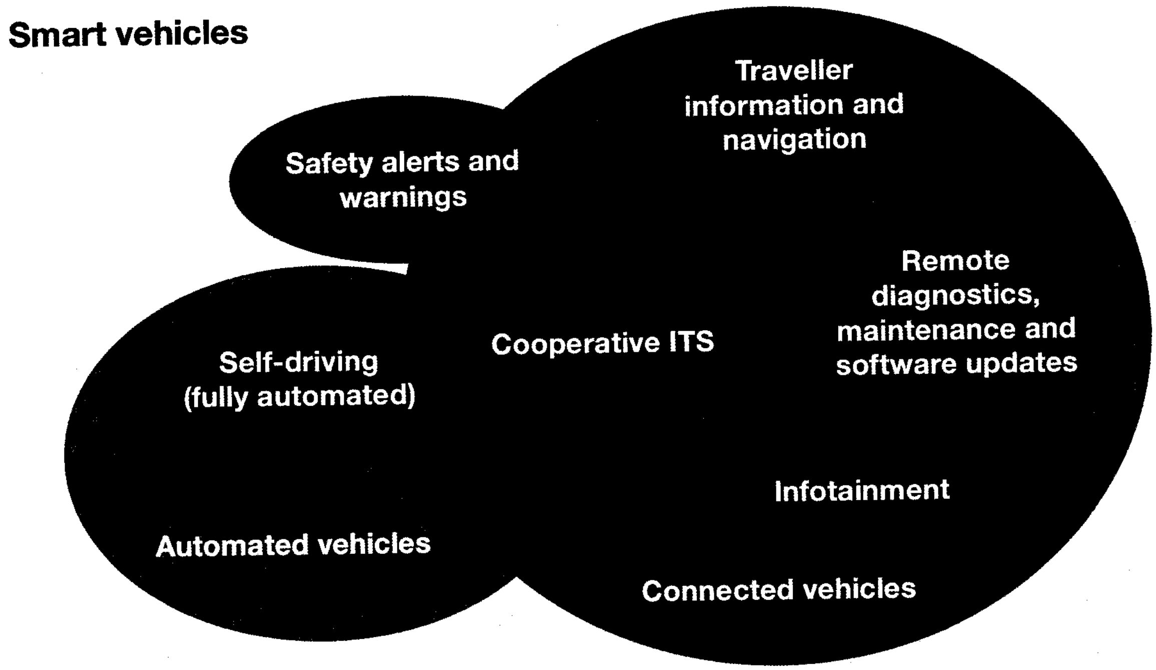

Figure 1.1 Automated and Connected Vehicles (Source: Main Roads, 2015a)

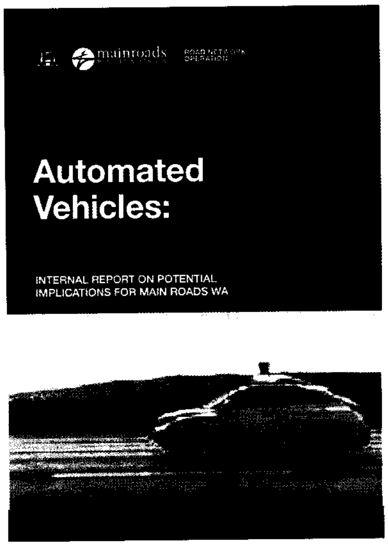

Figure 1.2 "Automated Vehicles: Are we ready?" report highlights the potential implications of AVs

Current attitudes, outside those who are directly involved in ITS, indicate a 'false sense of security' within Main Roads that developing technology such as C-ITS is largely driven by industry, and that anything we need to do on the roadside may be rolled into some national effort in the future.

1.2 Purpose of this report

In 2015, Main Roads produced the 'Automated Vehicles: Are we ready?' report[1] (Main Roads, 2015a) to highlight the implications for Main Roads of the introduction and wider use of AVs. This report discusses AVs, and it covers CVs only to the extent required to support its primary topic.

Following the release of the AVs report, the need to develop a similar report for CVs was identified. 'Connected Vehicles: Are we ready?' highlights the imminent availability of C-ITS enabled vehicles on Western Australian roads and what we, as the state road authority, need to do for C-ITS enabled vehicles to operate successfully.

The United States (US) and European Union (EU) car manufacturers have been working to include Cooperative Intelligent Transport Systems (C-ITS) in their new vehicles in the 2016-2020 timeframe, while Japan has already deployed vehicles with Vehicle-to-Infrastructure (V2I) and Infrastructure-to-Vehicle (I2V) C-ITS capability.

Currently, more than 85 percent of Australia's new vehicles are imported, and the majority of them are either US, EU or Japanese brands. All major Australian car manufacturers wind down operations, and the Federal Government considers relaxing the conditions for importing new vehicles. Therefore, it is likely that we have C-ITS enabled vehicles on our road network at almost exactly the same time they are deployed internationally.

Current attitudes, outside those who are directly involved in ITS, indicate a 'false sense of security' within Main Roads that developing technology such as C-ITS is largely driven by industry, and that anything we need to do on the roadside may be rolled into some national effort in the future.

As a result, national preparation for C-ITS may not have been given its due priority, and Main Roads may be required, with some urgency, to roll out the roadside infrastructure in time for C-ITS enabled vehicles start to arriving.

This report is prepared as a companion to 'Automated Vehicles: Are we ready?'. Where appropriate, the reader is guided to refer to the relevant sections of the 'Automated Vehicles: Are we ready?' report[1] for further information.

1.3 What are Connected Vehicles?

In general, 'Connected Vehicle' is used to broadly identify any 'smart vehicle' with:

- wireless connectivity to the Internet, local area network or the Cloud
- other vehicles
- personal communication devices
- roadside infrastructure
- control centres for real-time communication or data exchange.

[1] This report can be found at https://www.mainroads.wa.gov.au/Documents/Automated%20Vehicle%20Report.RCN-D15%5E2381741.PDF

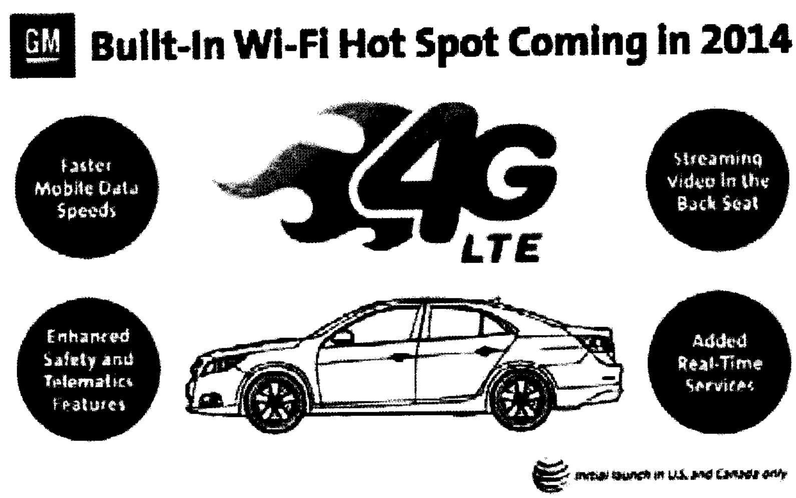

Figure 1.3 General Motors' promotion of Connected Vehicles (Source: General Motors)

Figure 1.4 A conceptual representation of C-ITS (Source: USDOT)

The 'wider' meaning of the term emphasises connectivity to the Internet and wireless Local Area Network (LAN) and can be encapsulated in the following definition of 'connected car' in Wikipedia (Wikipedia, 2015):

"A connected car is a car that is equipped with Internet access and usually also with a wireless LAN. This allows the car to share Internet access to other devices both inside and outside the vehicle. Often the car is also outfitted with special technologies that tap into the Internet access or wireless LAN and provide additional benefits to the driver. Examples include automatic notification of crashes, notification of speeding and safety alerts".

In this context, CVs also include services like traveller information and navigation, infotainment, remote diagnostics, maintenance, software updates, as well as safety alerts and warnings as in Figure 1.1.

1.4 What is Cooperative ITS?

C-ITS has a strong focus on Vehicle-to-Vehicle (V2V) and V2I, using wireless communication to share real-time information about the road environment (such as potential incidents, threats and hazards) with an increased time horizon and awareness distance that is beyond both what in-vehicle technologies (radars or cameras) and the driver can visualise (Austroads, 2012a). C-ITS can be considered a subset of CVs (Main Roads, 2015a).

Other aspects of CVs such as infotainment and remote diagnostics are being developed and deployed by vehicle manufacturers and technology companies independently of road agencies. This report focuses on the C-ITS component of CVs as this has the greatest implications for road infrastructure and road agencies.

C-ITS is a form of ITS that enables real-time communication (data exchange) between all or some of the nodes illustrated in Figure 1.5. It primarily improves safety, but can also improve productivity, efficiency and environmental outcomes on the road transport system.

C-ITS includes the following ITS sub-systems:

- vehicles (V)
- roadside infrastructure or field devices such as traffic signals and electronic signs (I)
- nomadic wireless personal devices (smart phones, personal communication devices etc.) carried by travellers including pedestrians and cyclists (P)
- control centres (such as transport management centres and emergency management centres) (CC)
- the Cloud (C)

V2V and V2I communications create a continuous wireless link enabling cooperation between vehicles and roadside infrastructure. The term 'cooperative' refers to the ability for vehicle and transport systems to dynamically exchange data and work collaboratively together to deliver outcomes beyond what standalone systems can. It also refers to the possibility of multiple applications working together in order of priority through a single in-vehicle operating platform (Austroads, 2013a).

Some early in-vehicle telematics applications in Australia, such as those listed below (Austroads, 2012a), include some V2I, I2V, V2C (Vehicle-to-Centre or Vehicle-to-Cloud), or C2V (Centre-to-Vehicle or Cloud-to-Vehicle) communications.

- Transport Certification Australia (TCA)'s Intelligent Access Program (IAP)
- the provision of routing and congestion information to vehicles via applications such as SUNA Traffic
- Electronic Toll Collection (ETC)
- commercial fleet management systems

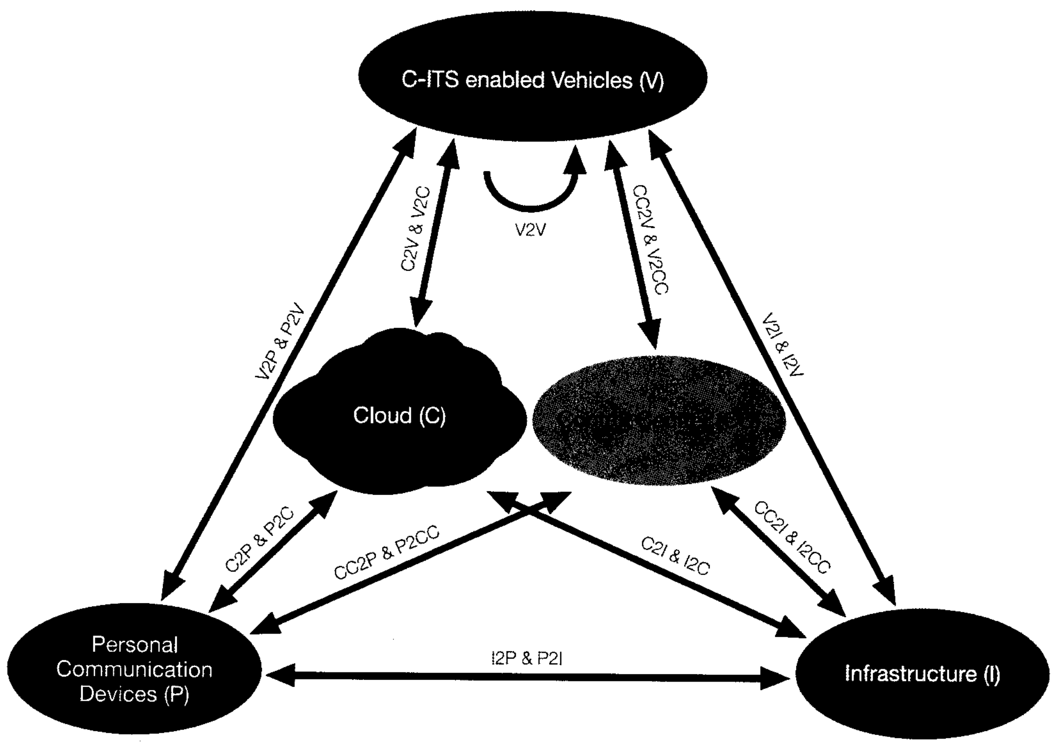

Figure 1.5 C-ITS connectivity (Source: Adapted from Austroads 2012a)

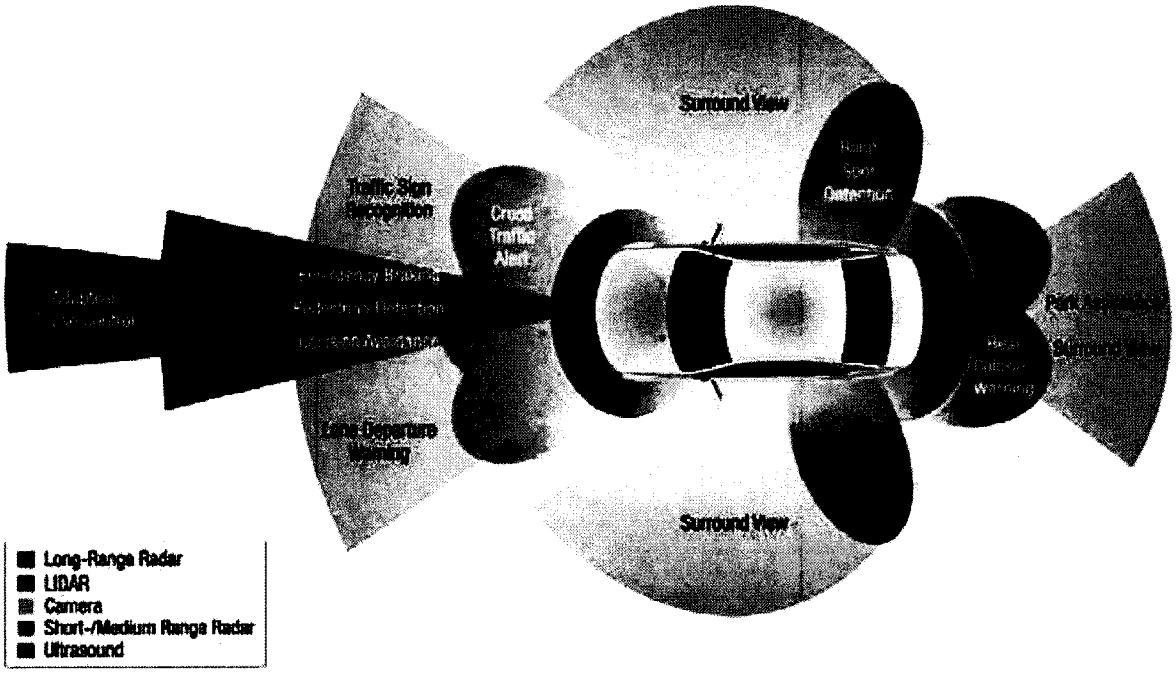

Figure 1.6 Vision-based ADAS (Source: BDTi)

1.5 C-ITS and Advanced Driver Assistance Systems

C-ITS allows communications to be more targeted to specific vehicle types and locations, and enables the vehicle's on-board Advanced Driver Assistance Systems (ADAS) (e.g. for safety applications) to react or send messages directly to vehicles from service centres via backhaul systems (e.g. to reduce response times for incident management) (Austroads, 2013a).

ADAS refers to a range of on-board 'active' safety systems, which assist drivers to avoid or reduce the impacts of a road crash (ERTICO, 2010a, cited in Austroads, 2013a). Many ADAS systems are already on the market, built into vehicles by the Original Equipment Manufacturers (OEMs). Most ADAS applications currently available rely primarily on on-board sensors, and include Electronic Stability Control (ESC), Electronic Brake-force Distribution (EBD), and Adaptive Cruise Control (ACC). A number of emerging ADAS applications require on-board sensors to work together with Global Navigation Satellite System (GNSS) positioning and a digital map. Examples of these map-enabled ADAS applications include Intelligent Speed Adaption (ISA) and curve warning applications.

C-ITS extends traditional ADAS beyond the internal environment of the vehicle's sensors by expanding the information, time and capacity to respond to events by using wireless communication. With ADAS systems becoming technically and commercially feasible – at an initial stage as information services only – high quality map content becomes a prerequisite for their success. (ERTICO, 2010b, cited in Austroads, 2013a).

The main impetus for deploying C-ITS, from a government perspective, is to deliver advanced safety applications that will aid in reducing the number of fatality and serious injury crashes on the road network (Austroads, 2013a).

In order to address road safety, C-ITS needs to function in urban and rural areas, particularly as rural areas contribute to a significant proportion (58 percent) of fatal crashes in WA (based on 2009–2014 crash data).

The main impetus for deploying C-ITS, from a government perspective, is to deliver advanced safety applications that will aid in reducing the number of fatality and serious injury crashes on the road network (Austroads, 2013a). In order to address road safety, C-ITS needs to function in urban and rural areas, particularly as rural areas contribute to a significant proportion (58 percent) of fatal crashes in WA (based on 2009–2014 crash data).

1.6 Emerging C-ITS applications

International C-ITS research by the European Telecommunications Standards Institute (ETSI) identified 32 emerging C-ITS applications shown in Table B.1 in Appendix B (ETSI, 2010, cited in Austroads, 2013a). A subset of these is likely to be selected for initial deployment when the C-ITS platform is standardised and implemented (Austroads, 2013a).

Of the emerging C-ITS applications on the ETSI list, those considered most likely to be adopted in Australia include the following.

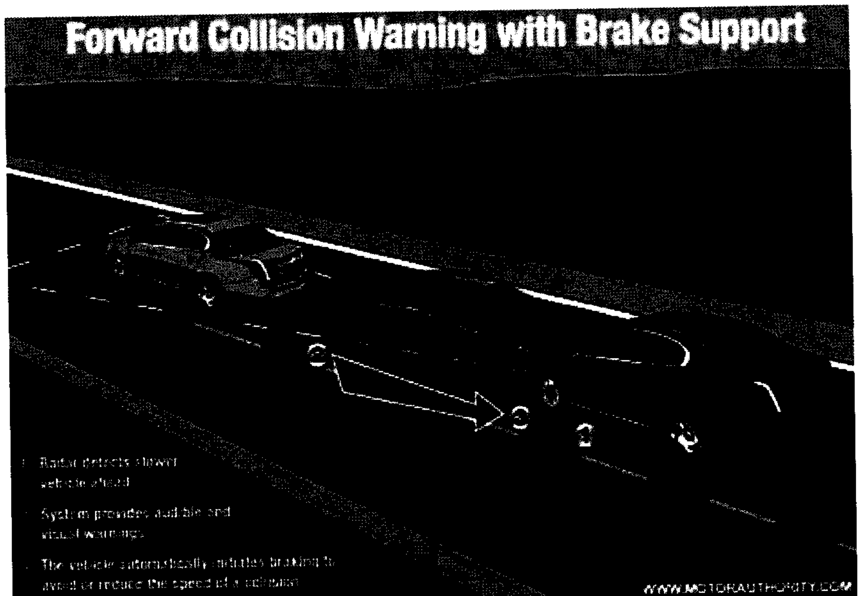

Figure 1.7 Forward collision warning (Source: Motorauthority)

Safety:

- Emergency vehicle warning (ETSI UC001)
- Intersection collision warning (ETSI UC003)[2]
- Motorcycle approaching warning (ETSI UC004)
- Emergency brake lights warning (ETSI UC005)
- Traffic condition warning (ETSI UC009)
- Collision risk warning (ETSI UC012)[2] (see Figure 1.7 for an illustration of a collision risk warning system)
- Regulatory/contextual speed limit notification (ETSI UC018)[2]
- Traffic light optimal speed advice (ETSI UC019)[2]
- Driver fatigue for light and heavy vehicles (to be developed and considered as an Australian addition to the 32 applications or use cases).

Network efficiency:

- Enhanced route guidance and navigation (ETSI UC021)[2]
- Limited access warning (ETSI UC022)[2]
- In vehicle signage (ETSI UC023)[2]

[2] Applications which will require highly accurate digital mapping data (enhanced maps)

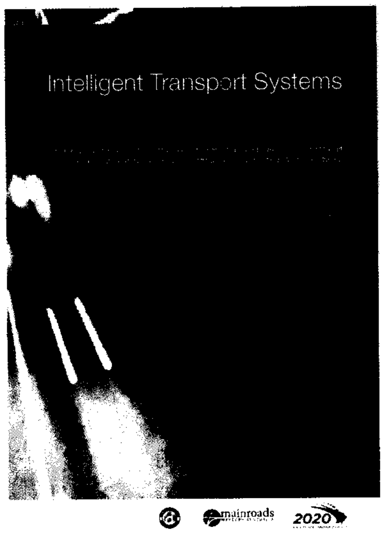

Figure 1.8 Main Roads' ITS Master Plan

[3] This document is to be reviewed in 2015/16.

1.7 C-ITS in the context of Main Roads' ITS Master Plan

Main Roads ITS Master Plan[3] (Main Roads, 2014), recognises smart vehicles as a key international driver for the future of ITS in WA.

The ITS Master Plan identifies that improved connectivity and cooperation between vehicles, roads and travellers as an aspect of what 'Smart Roads, Safe Journeys' would look like in 2020, which is also in line with Main Roads new strategic direction of 'Keeping WA Moving' (Main Roads, 2015b). 'Encourage and facilitate adoption of smarter, safer vehicle and road technologies' is an external focus area identified in the ITS Master Plan, with key actions for C-ITS as follows:

- Explore other speed and hazard warning roadside technologies.
- Continue cooperation with relevant national bodies, industry and advocacy groups in regard to safer, smarter vehicles.
- In collaboration with Department of Transport and other stakeholders, develop a strategy to facilitate the adoption of automated and connected vehicles.
- Identify high priority vehicle safety technology and implement required changes to infrastructure standards.
- Implement roadside units at high priority locations.
- Expand ITS control system functionality to allow for benefits from cooperative and multi-modal systems.

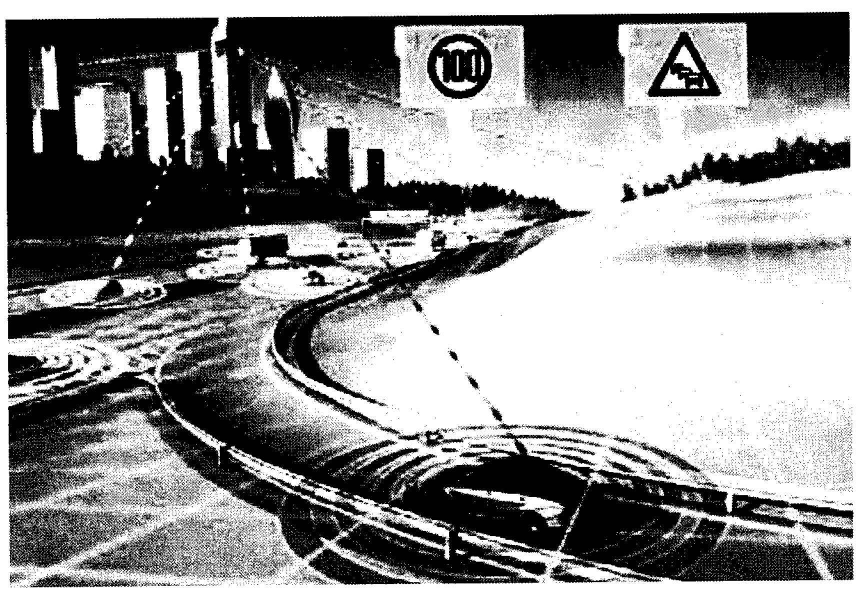

Figure 1.9 C-ITS will enable delivery of traffic and road condition information via in-vehicle telematics directly to the driver in real-time (Source: HERE)

2. Benefits of Connected Vehicles

The benefits of CVs are wider than those delivered by C-ITS and encompass the areas of safety, travelling information, mobility, infotainment and remote diagnostics, as well as maintenance and software updates.

The potential benefits of C-ITS are more focussed in the areas of safety, efficiency and environment and are highlighted by the objectives for the deployment of C-ITS in Australia as described in the 'Austroads Cooperative ITS Strategic Plan' (Austroads, 2012a) including:

- reducing the number of fatalities and serious casualties caused by road crashes
- reducing the costs associated with road trauma
- reducing traffic congestion
- improving productivity in road infrastructure use
- reducing the environmental impacts of road transport, through less emissions and fuel use.

2.1 Safety

Communication between vehicles, and between vehicles and infrastructure will enable the substantial safety benefits of CVs to be realised, as these communication functions act as a countermeasure for many different types of crashes.

The US National Highway Traffic Safety Administration (NHTSA) cited US Department of Transportation (USDOT) analysis concluding, as a primary countermeasure, a fully mature Vehicle-to-Anything (V2X) system could potentially address:

- about 4,409,000 police-reported or 79 percent of all vehicle target crashes
- 4,336,000 police-reported or 81 percent of all light-vehicle target crashes
- 267,000 police-reported or 81 percent of all heavy-truck target crashes annually (NHTSA, 2014a).

In its policy considerations, Australia's National Transport Commission (NTC) used a more conservative Austroads analysis (Austroads, 2011) that predicted a 25-35 percent reduction in serious casualty crashes once V2X equipped vehicles achieved saturation of the vehicle fleet (NTC, 2013). Although this Austroads, prediction is lower than the figures used by NHTSA (partly because the Austroads' report only focussed on collision avoidance applications, whereas the US work included a range of safety applications), it is clear that CVs provide a step-change opportunity to significantly reduce fatalities and serious injury crashes.

However, it is important to note that there is potential for certain aspects of CVs to increase safety risks, particularly given the inclusion of technologies like infotainment. As a result, assessing the safety benefits of CVs should be measured against the net safety benefits after accounting for any increases in risk.

The greatest safety risks are driver distraction, driver over-reliance on technology and technology failure. While these areas warrant ongoing consideration, at this stage it appears feasible for any increased risks to be managed so they do not substantially reduce the net safety benefits of CVs.

Sections 3 and 5.3.2 provide further information on human factor issues.

2.2 Traveller information

Increased and continuous vehicle connectivity provides travellers with better information enabling them to make more informed decisions during their journey. CVs enhance information by providing updated route advice based on current traffic conditions, and can also use real-time congestion experienced to update information for other road users.

In addition to real-time congestion and incident information, other CV features include guided parking at destinations and train service disruption advice when using park-and-ride facilities. These features demonstrate the CVs ability to provide additional opportunities to value-add to traveller information services.

These value-added services are also likely to become more tightly integrated with mobile devices and the services they offer. For example, mobile devices will look at appointments in your calendar, work out where you next need to be and your best option to get there, without the question having to be asked. Furthermore, logistics and dispatch systems can capture real-time traffic condition information into route optimisation and vehicle selection to improve service and lower costs.

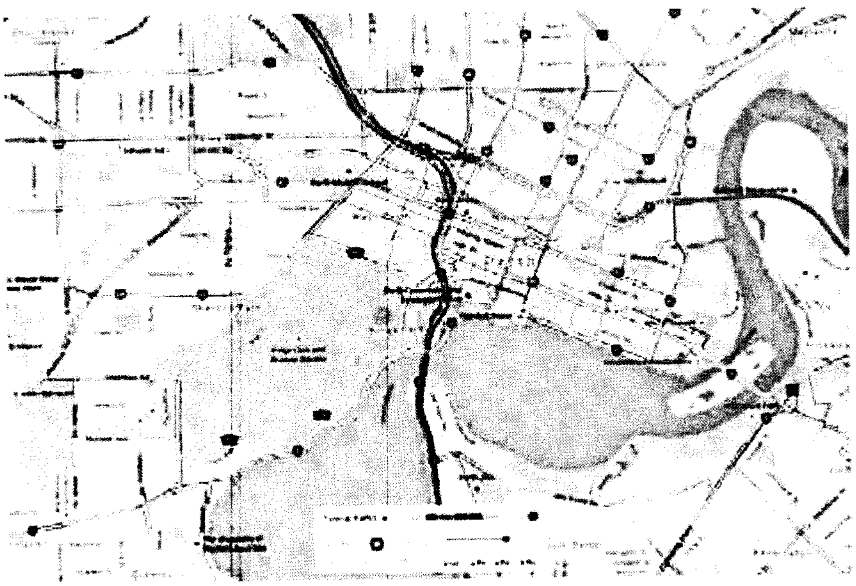

Figure 2.1 Real-time access to congestion information helps drivers to find the best route (Source: Google)

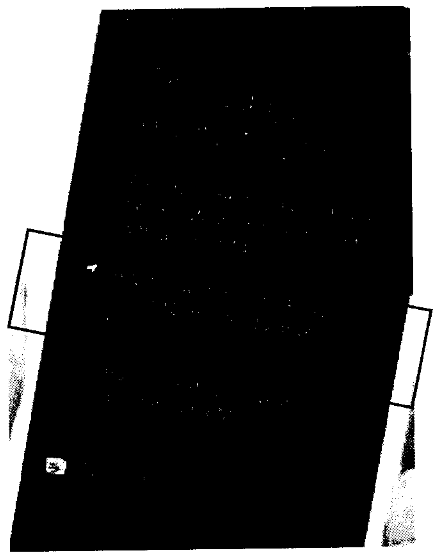

Figure 2.2 An example of traffic conditions integrated into calendars and schedulers (Source: imore.com)

This trend is likely to continue along with the demand for multi-modal information.

New traveller information services are not just limited to congestion and incident related information; for example, insurer AAMI (Australian Associated Motor Insurance Limited) has released a safe driver application that tracks length of trips, speed, acceleration, braking, fatigue and phone usage (AAMI, 2015). It then provides feedback to drivers through a safe driver score, and rewards high-scoring compliant drivers with free roadside assistance. Other applications provide feedback on environmentally friendly driving styles, and while they are currently seen more on smartphones, they are increasingly appearing in CVs.

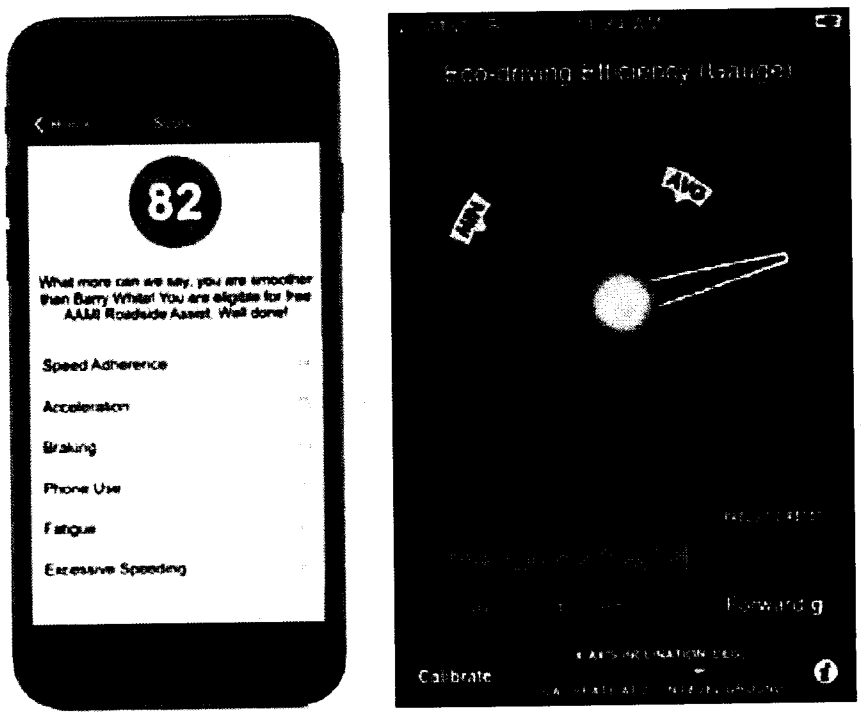

Figure 2.3 Apps available on smartphones and on vehicle systems encourage safer and more environmentally friendly driving (Source: AAMI and Stay-safe App)

While the advantages of using these sources and disseminating travel information to drivers is clear, there are a number of advantages for road authorities identified by Austroads (2014a) including:

- enhanced coverage (not limited to locations of roadside infrastructure) for both probe vehicle data and message/alert delivery
- access to new data types, such as origin-destination information
- fusing multiple data sources to improve information accuracy.

2.3 Mobility

The specific impact of CVs on improved mobility is more difficult to quantify than safety benefits. However, more informed choices and providing enhanced information to travellers will assist in reducing congestion and therefore improve mobility.

USDOT advises that while there is no comprehensive analysis of the potential impacts of CV systems on urban congestion, the focus of certain applications on reducing travel delays should ensure that benefits will accrue in this area (USDOT, 2014a).

Applications classed by AASHTO (American Association of State Highway and Transportation Officials) as mobility-related are shown in Table 2.1 (AASHTO, 2013).

Many of the CV services that provide mobility benefits also improve the efficiency of vehicle operations that in turn contributes to reduced fuel consumption and emissions.

2.4 Road operator benefits

USDOT identified that CVs could provide vital data including weather, road conditions and structural asset information to assist with the management of the road network. Currently, on-board systems in newer cars collect a lot of information that could be used by road operators and authorities to track physical asset information and convey weather and road hazard information back to travellers (USDOT, 2014a).

For example, USDOT collects weather information regarding winter snow and ice clearing; while this is not relevant for WA, there is the potential to receive and transfer relevant weather data for severe weather and emergency conditions in WA such as cyclones, flooding and bushfires.

Table 2.1 Mobility-related C-ITS applications (Source: AASHTO, 2013)

Application	Description
Cooperative Adaptive Cruise Control (CACC)	Cooperative adaptive cruise control has the potential to significantly increase traffic throughput by tightly coordinating in-platoon vehicle movements to reduce headways between vehicles. The lead vehicle broadcasts location, heading and speed. CACC-enabled following vehicles automatically adjust speed, acceleration and following distance. The cooperative nature of the function means that vehicles can safely operate at closer headways than if operating autonomously.
Emergency Vehicle Pre-emption (EVP)	Emergency vehicle pre-emption provides strong traffic signal priority for emergency vehicles, reducing emergency response times as well as improving responder and general road user safety.
Transit Signal Priority (TSP)	Priority for public transport vehicles at intersections can improve the reliability and speed of public transport services. This increases the attractiveness of public transport as well as reducing the cost of providing the public transport service.
Cooperative Traffic Signals	The use of high-fidelity data collected from vehicles through wireless communications will facilitate accurate measurements and predictions of lane-specific platoon flow, platoon size, and other driving characteristics. Developing new systems that use data via V2V and V2I wireless communications to control signals in order to maximise flows in real-time can improve traffic conditions significantly.

CVs could provide vital data including weather, road conditions and structural asset information to assist with the management of the road network.

2.5 Other benefits of connectivity

The benefit areas covered so far align with the objectives of road agencies: safety, movement/mobility; sustainability; and customer service. CVs will also provide benefits in areas such as personal entertainment, vehicle operations and engine management.

2.5.1 Infotainment

The popularity of smartphones, tablets and other mobile devices is contributing to a trend for vehicle infotainment systems that is largely driven by collaboration between technology companies and vehicle manufacturers. There are five major smartphone-style operating systems currently competing for market share in vehicle infotainment.

- Apple CarPlay to bring iOS (as used on iPhone and iPad) into the vehicle.
- GENIVI Alliance was established by car manufacturers in 2009, working on an open source development environment using the Meego operating system.
- Google's Open Automotive Alliance is working to bring 'Android Auto' into vehicles.
- Microsoft's Windows Embedded Automotive is descended from AutoPC and Windows CE for Automotive developed 15 years ago, and is currently used in Ford's Sync and Sync 2 systems available in Australia in many Ford vehicles.
- The maker of Blackberry smartphones Research in Motion (RIM)'s QNX platform is starting to be used, including in Ford's Sync 3.

The move towards consumer infotainment platforms is happening in parallel with the move towards greater connectivity from in-vehicle systems. This happens either by the vehicle accessing the data connection of a mobile device via Bluetooth pairing, or when the vehicle has its own SIM (Subscriber Identity Module) card and data connection.

Road authorities are interested in better and safer in-car systems that offer better Human-Machine Interfaces (HMI) that reduce the drivers desire to manipulate mobile phones and other items while on the move; however, they have limited interest in drivers' ability to access services such as streaming Internet radio.

Connectivity that drivers are prepared to pay for to access such infotainment does open up the opportunity for car manufacturers to package, at no extra cost, tools that are directly safety and mobility focussed, such live traffic information and emergency call (eCall) services.

2.5.2 Remote diagnostics, maintenance and software updates

Other technology extends outside of infotainment, to safety and vehicle control functions. Keeping this technology up to date is a significant challenge for car manufacturers given that the average age of the Australian vehicle fleet is 10 years.

Figure 2.4 Connected infotainment brings services such as personalised Internet radio to drivers (Source: Chevrolet)

Most vehicles currently receive few, if any, updates to their technology during their service life. This is starting to change, with vehicle manufacturers beginning to implement technology platforms that allow for software updates during the life of the car, including to core safety and driving support systems.

Electric vehicle manufacturer Tesla is arguably the most advanced in providing software updates. Tesla provides regular updates using cellular data networks to avoid the need to bring cars to a service centre. Tesla's software updates also have the potential to make significant changes to the interior look and feel of the vehicle as the dashboard is made up of a series of LCD (Liquid Cristal Display) screens rather than traditional dials.

> In 2014 Tesla addressed a vehicle recall by using an over-the-air software update where by the vehicles were updated in driveways overnight, minimising owner inconvenience and reducing manufacturer costs by removing the need to visit a service centre.

In 2014 Tesla addressed a vehicle recall by using an over-the-air software update whereby the vehicles were updated in driveways overnight, minimising owner inconvenience and reducing manufacturer costs by removing the need to visit a service centre (Wired, 2014). In the future, Tesla intends to continue to use over-the-air software updates to add more advanced automated vehicle functions to their cars.

3. Human factor issues

Human factors including driving behaviour, capabilities and limitations, an over-reliance on new technology and a failure to use the available technology offer a number of challenges for CVs as outlined in NTC (2013) and based on a discussion with Professor Mike Regan[4].

3.1 Drivers' over-reliance/ behavioural adaptation

With all new driving technology there is a risk that drivers will become over-reliant or adapt their behaviour leading to a loss of skills or unsafe behaviour developing because drivers rely on the technology rather than their skills. For example, where the use of a reverse collision warning leads to drivers' failing to look behind them when reversing. Avoiding false expectations will be important to ensure safety (Rand Corporation, 2009, cited in NTC, 2013). Systems always have limits and adaptations can lead to additional dangers, particularly in an environment where not all vehicles are connected.

3.2 Awareness of capabilities and limitations

Education about system capabilities and limitations is important to ensure users do not overestimate any system's capability.

3.3 Risk compensation

Risk compensation is an issue faced by all new safety systems. It is the notion that drivers may drive in a more risky fashion due to a greater feeling of safety as a result of additional safety systems.

3.4 Distraction

As in-car systems and their interfaces become more complex driver distraction is an increasing concern. Designers will need to ensure warnings are not startling and that the design of information is ergonomically appropriate. Well-designed warnings should be carefully calibrated in the sense of being decipherable, comprehensive, parsimonious, obvious and executable (Van Wees and Brookhuis, 2005, cited in NTC, 2013).

NTC (2013) has recommended that driver distraction arising from C-ITS should be considered as part of any broader review of driver distraction rather than in isolation (also refer section 5.3.2 for further details).

3.5 Risk exposure change

Changing technology can affect people's travel patterns, and result in a change in their exposure to risk. An example is GPS (Global Positioning System) navigation systems, which may have led more drivers to complete trips in unfamiliar locations, increasing their driving and changing their risk exposure. The changes to driving and travel patterns as a result of C-ITS are currently difficult to predict.

3.6 Skill loss

Increasing driver aids may lead to a loss of driver skill, which can be critical when a driver aid fails and the driver no longer has the collision avoidance skills to deal with a critical situation. Airlines seek to avoid this with their pilots by using flight simulator training.

In comparing automatic cruise control and C-ITS applications, the European Commission (EC)'s Cooperative Vehicle-Infrastructure Systems (CVIS) project found that the overall probability of a simultaneous failure of an automated system and the driver resulting in an accident, is the product of the probability of a system failure and the probability of a failure by the driver to respond if the system cannot (Verweij *et al*, 2010, cited in NTC, 2013).

Clearly, the issue here is to ensure that the level of driver attention does not fall so low that the overall

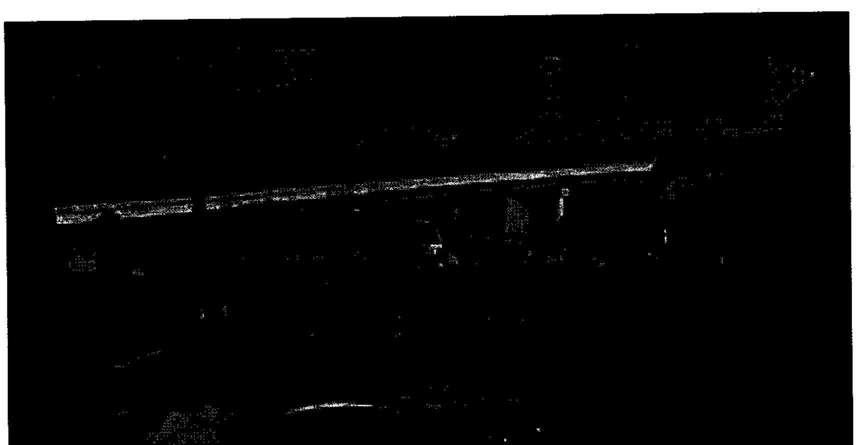

Figure 3.1 Heads-Up-Display (HUD) technology (Source: Microvision)

[4]Professor Michael Regan is currently the Chief Scientist – Human Factors at ARRB Group.

performance is worse than without the system. In fact, the result needs to be substantially better in order to justify the benefits.

3.7 Driver acceptance

Drivers may not accept and use the technology available. A historical example of this is seat belts, where regulation was eventually required to ensure that seat belts were fitted on all vehicles to change driver and passenger habits (there still remains a percentage of drivers and passengers who do not use them).

Regulatory policy issues can also have an effect on public perception and uptake – will the public perceive these systems as a benefit to themselves and their safety? Initial studies indicate strong public interest, with a recent on-road trial in the US finding that more than 90 percent of the participants believed a number of specific features of the connected vehicle technology would improve driving in the real world, including: features alerting drivers about cars approaching an intersection; warning of possible forward collisions; and notifying drivers of cars changing lanes or moving into the driver's blind spot (NHTSA, 2012, cited in NTC, 2013).

The study did also indicate a limit on what consumers are willing to pay, with drivers indicating that such systems would not be worth purchasing if they were over USD 250 (AUD 284). Regulatory policy issues – in particular privacy, compliance and enforcement issues – may also have a significant impact on acceptance.

Based on identified gaps in international research that are relevant to Australia, NTC (2013) has recommended that research is conducted to measure the human factor impacts of C-ITS applications, and to determine whether any mitigating policy measures are required in order to obtain the safety benefits without creating additional risks.

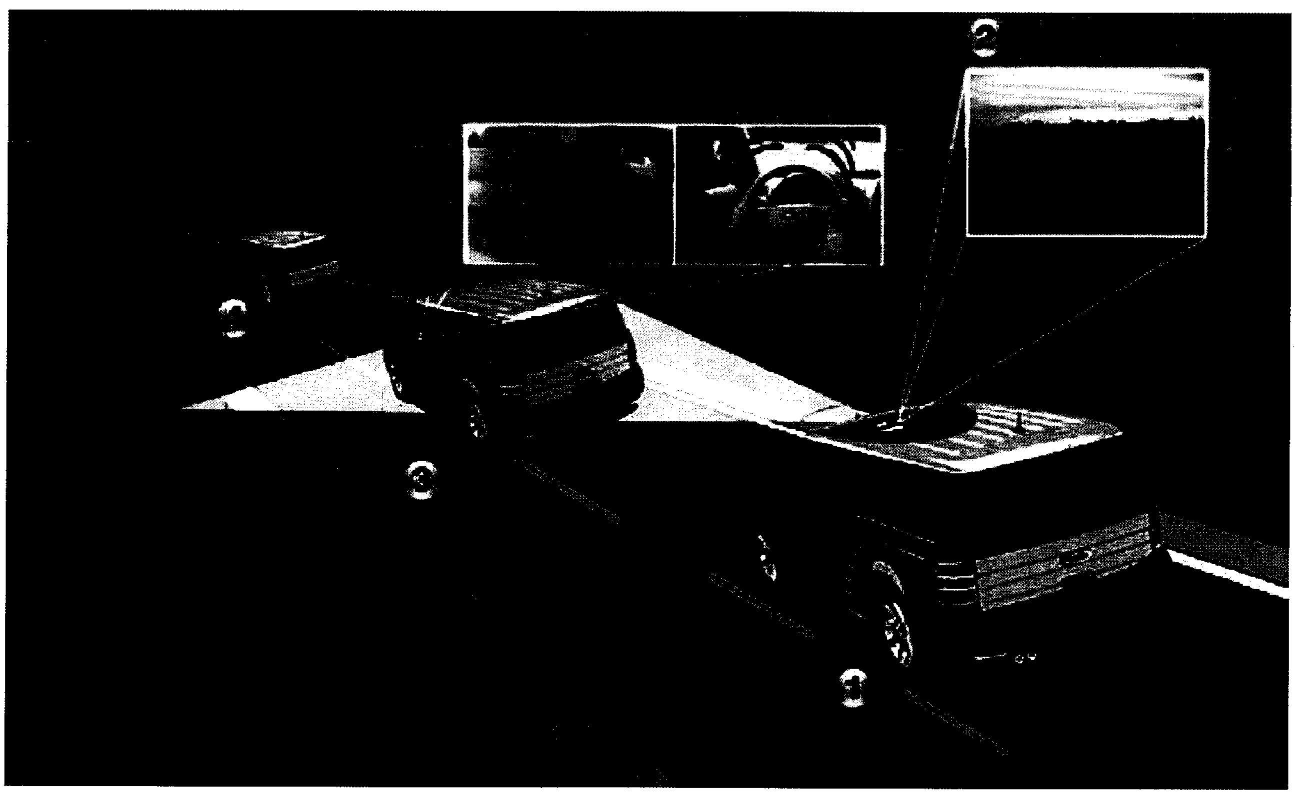

Figure 3.2 Lane departure warning provided as both audible and haptic warnings (Source: www.huffingtonpost.ca)

4. What is happening globally?

4.1 United States

4.1.1 Rulemaking for V2V communication

The US is at the forefront of the development of CVs and C-ITS. NHTSA is in the process of rulemaking to require new light vehicles to be equipped with V2V communication capability. However, NHTSA rulemaking is an arduous process. After several years of research in key areas including feasibility, privacy and security, and preliminary estimates of costs and benefits, the status of the NHTSA rulemaking process regarding V2V communication is summarised below (NHTSA, 2014b).

- February 2014: announced intent to progress to regulation
- August 2014: issued advance notice of proposed rulemaking
- 2016: plans to issue a notice of proposed rulemaking

In 2014 General Motors (GM) announced that one new Cadillac model would come with V2V as standard from 2016. However, some auto-manufacturers do not appear to want V2V mandated on vehicles. If the rulemaking is completed during 2016, there is still likely to be some lead-time before the requirement for V2V communication capability comes into force.

4.1.2 CV pilot deployments

In addition to progressing regulations, the research and development efforts on C-ITS in the US continue to grow. Following on from the large scale Safety Pilot Model Deployment involving 3000 C-ITS equipped vehicles in Detroit, USDOT

In 2014 General Motors (GM) announced that one new Cadillac model would come with V2V as standard from 2016.

is supporting two waves of CV pilot deployments in late 2015 and late 2017. The pilot deployments are intended to support private sector innovation and early adopters of C-ITS and they will have an extensive range of applications included covering:

- V2I safety
- V2V safety
- agency data collection
- environment
- road weather
- mobility
- smart roadside (USDOT, 2014c).

Examples of previous C-ITS pilot deployments, and other C-ITS research and development in the US are outlined in Main Roads (2015a) including University of Michigan Transportation Research Institute (UMTRI), California PATH, the Florida DOT Connected Vehicles test-bed, the University of Virginia Connected Vehicle Infrastructure-University Transportation Centre (CVI-UTC), and the supporting Connected Vehicle Reference Implementation Architecture (CVRIA).

4.1.3 V2I applications

Private sector innovation is starting to offer some V2I functions through mobile communications. For example, the EnLighten App by Connected Signals can provide alerts that traffic signals are about to turn green. This is prediction based using current signals state, timing plans, the time of day, vehicle and pedestrian calls, and historical behaviour (Connected Signals, 2015).

By using predictions and providing warnings of imminent green rather than the more safety critical imminent red, EnLighten is less dependent on latency than proposed Cooperative

Figure 4.1 EnLighten App can provide alerts that traffic signals are about to turn green (Source: Connected Signals)

Traffic Signals that use V2I DSRC communications. This allows faster and lower cost deployment of a single back-office connection to the traffic signal system and mobile communications to users, but significantly reduces available function. In addition to a number of US cities, EnLighten appears to be operational in Christchurch in New Zealand, and in progress for Melbourne and Sydney in Australia.

4.1.4 Other CV applications

The wider applications of CVs such as infotainment, live traveller information (via mobile networks), emergency assistance, and remote diagnostics and maintenance are all in operation in the US, primarily through private sector-led innovation.

4.1.5 Challenges to preserving 5.9 GHz band

Despite the positive momentum, the journey of C-ITS in the US is far from smooth. The *Wi Fi Innovation Act* has been introduced as a bill to the US Congress. If enacted, it would open up the 5.9 GHz spectrum currently reserved for DSRC for ITS to use by unlicensed Wi-Fi devices similar to the current 2.4 GHz and 5.8 GHz bands. This bill is opposed by the USDOT, US automakers and ITS America all of whom fear the impact on C-ITS.

Even if enacted, the bill does not necessarily mean the end of DSRC in the US as there are some elements of the bill that offer protection for continued ITS use of the band. Currently, www.govtrack.us rates the bill with only a three percent likelihood of being enacted (GovTrack, 2015).

4.2 Europe

With the US and Japan, Europe has been a major centre for CV and C-ITS developments around the world. EC funded a series of successful C-ITS projects including COOPERS, CVIS, and SAFESPOT, which were completed around 2010/11, and Compass4D (Main Roads, 2015a). These EU projects had a dual focus on developing support technology and demonstrating applications involving two-way data communication between vehicles and road networks (Jandrisits, 2013).

4.2.1 Concept of 'Connected Mobility'

The EU position on cooperative systems is to understand them as 'Connected Mobility' that extend beyond V2V and V2I and goes hand-in-hand with an increase of vehicle automation (Alfayate, 2014). Cooperative systems will be used to connect all the elements of the transport chain (including public transport and vulnerable road users - pedestrians, cyclists, motorcyclists). This vision of Connected Mobility is one that contributes to multiple policy objectives including:

- improving road safety;
- enhancing mobility & reducing congestion;
- optimising performance & transport infrastructure capacity ;
- increasing real time reliability;
- improving efficiency of logistic operations; and
- (indirectly) reducing energy use & environmental impacts.

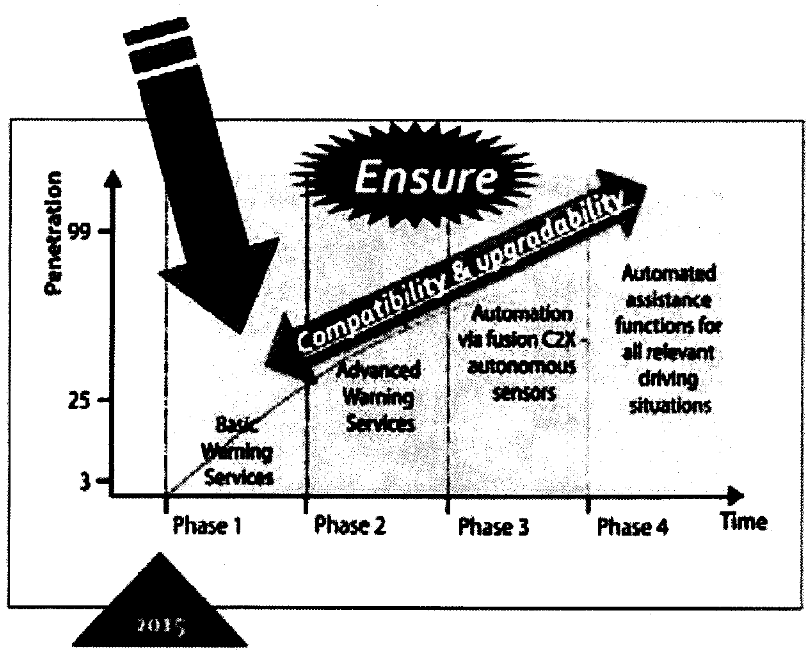

Figure 4.2 Phased deployment approach focus on day-one services (Source: Amsterdam Group)

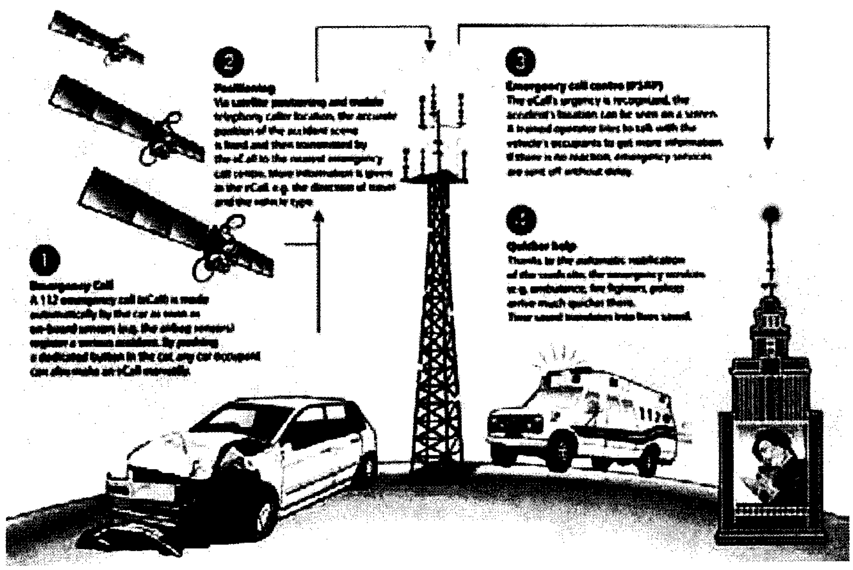

Figure 4.3 eCall, Europe's automated emergency notification system (Source: EC)

An EC focus is the development of a shared vision and a roadmap for deploying cooperative systems in the EU, in a partnership between the public and private sectors (Alfayate, 2014).

The expectation is that C-ITS in Europe will follow a phased deployment approach with non-complex day-one services provided even with limited penetration of ITS in vehicles by using Road-side Units (RSUs) in 'hot spot' areas and corridors as in Figure 4.2. In subsequent phases, the increased penetration of equipped vehicles allows the use of crash avoidance applications. The final phase is a service environment where the road infrastructure is completely integrated with the cooperative capabilities of the vehicles (Amsterdam Group, 2013).

4.2.2 eCall

eCall is an emergency notification service, activated automatically as soon as in-vehicle sensors detect a serious crash.

When activated, the system dials the European emergency number 112, establishes a telephone link to the appropriate emergency call centre and sends details of the accident to the rescue services, including the time of incident, the accurate position of the crashed vehicle and the direction of travel. The data received through the eCall system allows emergency services to provide assistance to vehicle drivers and passengers more quickly.

eCall may be able to reduce emergency response times by 40 percent in urban areas and 50 percent in rural areas, saving up to 2,500 lives a year across Europe. All new models of cars launched in the EU from 31 March 2018 must have the eCall service, a delay from the originally proposed 2015 introduction (EU, 2013).

4.2.3 Other EU initiatives

Compass4D, which is an EU co-funded pilot project, and SCOOP@F in France, are examples of the significant C-ITS initiatives in Europe and are outlined in Main Roads (2015a). Additionally, three countries (the Netherlands, Germany and Austria) have committed to a Cooperative ITS Corridor Initiative for the route between Rotterdam and Vienna, via Frankfurt (Blervaque, 2014). The service on this corridor will issue roadwork warnings and collect vehicle probe data using both DSRC and 4G/LTE (Long Term Evolution) cellular communications.

4.3 Japan

4.3.1 Vehicle Information and Communication System

Japan made an early start in CVs with the 1996 start-up of the Vehicle Information and Communication System (VICS), which delivers detailed real-time traffic information to drivers nationwide (Suzuki, Kanazawa and Tsukiji, 2014).

VICS information (on traffic congestion, road regulations etc.) is edited and processed at the VICS Centre and is then transmitted in real time to car navigation systems where it is displayed in text and graphic form. VICS enables drivers to select the shortest, most convenient routes available, and ensures that traffic is distributed smoothly (PIARC, 2004).

Congestion and restriction information is collected by the highway operators and the local police as a part of their daily activity and the Japan Road Traffic Information Centre integrates the information provided by the respective agencies. Parking availability is collected by the individual parking operators.

4.3.2 ITS Spot

The next generation C-ITS service in Japan, the 'ITS Spot' was installed at 1,600 locations across Japan during 2011, mainly on expressways. The initial wave of ITS Spot services includes the following (Suzuki, Kanazawa and Tsukiji, 2014):

- Mobility service - including dynamic route guidance, wider area route selection support, destination travel time and still images of traffic conditions.
- Safety service - including congestion queue information, high-risk crash zones warnings, roadwork and obstructions warnings, weather information, still images of road surface condition and emergency information.
- Electronic Toll Collection (ETC).
- Collection of vehicle probe data.

As of the end of 2014, there were around 500,000 vehicles equipped with the on-board units that communicate with ITS Spot.

The ITS Spot service uses DSRC across the 5.8 GHz spectrum. In addition, Japan has allocated the 760 MHz channel for V2V. Applications in the 700 MHz spectrum are less advanced than ITS Spot, with field operational tests commencing in 2014.

4.4 Other countries

Main Roads (2015a) outlines some initiatives in South Korea, Singapore, China and New Zealand.

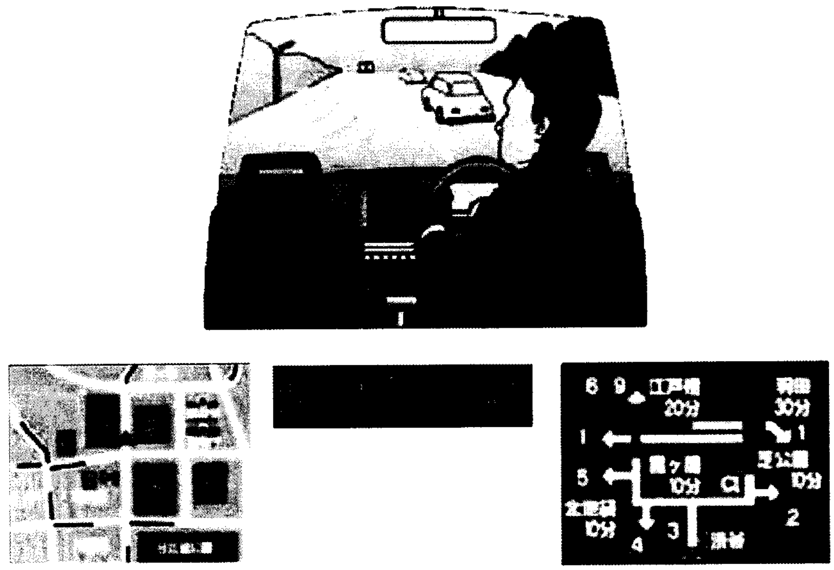

Figure 4.4 Japan's VICS (source: atip.org)

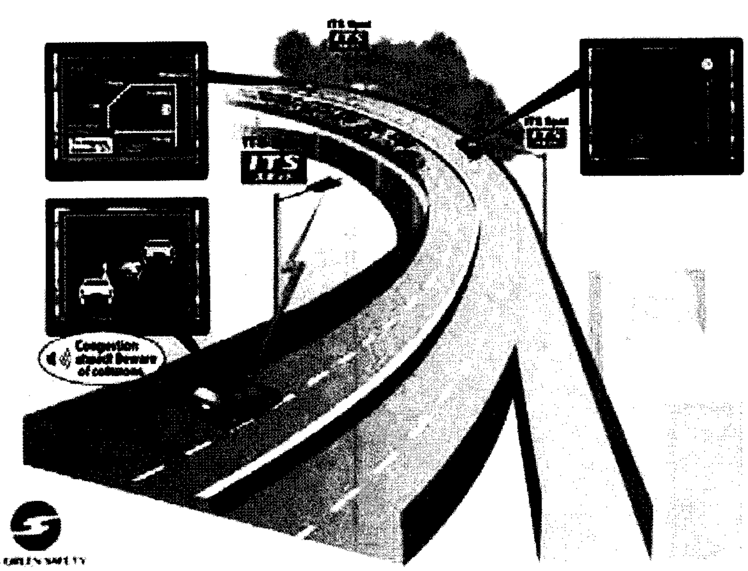

Figure 4.5 ITS Spot in Japan (Source: ITS-Japan)

5. Current state of play in Australia

Australia is currently actioning C-ITS in accordance with SCOTI[5]'s Policy Framework for ITS in Australia (SCOTI, 2012). This policy framework also established Austroads' current responsibilities for the development of C-ITS use of the 5.9 GHz band.

5.1 Core functions to support operationalization of C-ITS

Based on an assessment of international and local C-ITS developments, Austroads (2015a) has proposed that the following core functions are required to support C-ITS in Australia and New Zealand.

- secure exchange of data between users and applications
- trust in and integrity of data
- assured privacy between users and from third parties
- facilitate a platform for sharing data and the efficient use of resources
- assured national interoperability and consistent service access.

These core functions are often part of a physical system, or several physical systems, such as a C-ITS device in a vehicle or in several vehicles, centres, roadside infrastructure and mobile devices. They can be seen as a collection of operational and institutional functions, which will require policies and management structures as a basis to operate from (Faber *et al.*, 2014).

These core functions lead to the following three key foundation activities that will need to be in place to appropriately support C-ITS deployment.

- Spectrum management and device licensing – to ensure the 5.9 GHz band is formally allocated for ITS use, and that DSRC devices are appropriately managed and licensed to use the band.
- Assurance of standards compliance – to ensure technical standards that are critical for achieving safety and interoperability are complied with to an appropriate level.
- Security Credential Management System (SCMS) – to provide appropriate levels of security and trust in C-ITS equipment and the data that is communicated.

Key decisions will be necessary to determine the role of government with each of these core functions. This may require business cases and funding models to support investment decisions. More broadly, road agencies will also need to make informed benefit-cost decisions regarding the possible deployment of roadside infrastructure to support C-ITS applications (Austroads and DIRD, 2015).

5.2 Deployment challenges with C-ITS

5.2.1 Spectrum management and device licensing

Arrangements have been made internationally to allocate the 5 850 – 5 925 MHz band (the 5.9 GHz band) in the DSRC radio spectrum for C-ITS communications. The US, Canada and Europe are some of the first countries to allow the spectrum for C-ITS in the 5.9 GHz band.

C-ITS applications that are being developed internationally will require the use of 5.9 GHz radio spectrum band (Austroads, 2012a) and harmonising with international arrangements is vital for the introduction of C-ITS to benefit from economies of scale (ACMA, 2009).

One of the key requirements to support C-ITS deployment is to ensure the 5.9 GHz band is formally allocated for ITS use, and that the DSRC devices are appropriately managed and licensed to use the band (spectrum management and device licensing) (Austroads and DIRD, 2015).

The 5.9 GHz band is used by a range of services such as Fixed Satellite Services (FSS) (ACMA, 2009), therefore, sharing arrangements need to be in place to allow the introduction of a new C-ITS service into the band without interference and disruption to incumbents.

Road agencies will also need to make informed benefit-cost decisions regarding the possible deployment of roadside infrastructure to support C-ITS applications.

[5]Standing Council on Transport and Infrastructure (SCOTI) is now renamed as Transport and Infrastructure Council (TIC).

One of the key requirements to support C-ITS deployment is to ensure the 5.9 GHz band is formally allocated for ITS use, and that the DSRC devices are appropriately managed and licensed to use the band.

Investigations have been undertaken into potential interference including field studies looking at FSS sites operating in the 5.9 GHz band, and the future spectrum management and device licensing options (Zabrieszach, c.2013).

Upon a request from Austroads, the Australian Communication and Media Authority (ACMA), who is the government regulator of radio frequency spectrum in Australia, issued Embargo 48 in 2008 to protect the band from any additional licenses to enable further planning, investigation and consultation to occur. In April 2014, Austroads made a submission to ACMA requesting that the formal spectrum allocation process for the 5.9 GHz band proceed. It is anticipated that ACMA will make a formal decision in 2015/16 (Austroads and DIRD, 2015).

ACMA will play the lead role in allocating C-ITS use of the 5.9 GHz band and will determine a licensing regime for DSRC devices. However, there could be a number of ongoing activities, which may need to be established. (Austroads and DIRD, 2015):

- Develop and maintain coordination criteria to enable 5.9 GHz DSRC devices to coexist with other users within and near the band, and provide an escalation point for managing potential interference issues that occur between 5.9 GHz DSRC and other licensed users.
- Coordinate, monitor and audit 5.9 GHz DSRC road-side devices (also known as Road Side Units or RSUs), including the maintenance of a central register of road-side devices, to assist with ongoing compliance with license conditions and to facilitate compliance with the coordination criteria.
- Establish agreement with key stakeholders as to which standards, rules and processes relating to 5.9 GHz DSRC should be complied with.

Austroads has proposed to ACMA that a 'Class' license specific to C-ITS be established for 5.9 GHz DSRC. Class licensing puts the onus on entities that bring a device to market to ensure that it complies with license conditions. There usually is no license application that needs to be assessed or any license fee that is payable. Under a class licensing model it is anticipated that the effort required to undertake the activities above would be relatively low. However, if ACMA was to require an 'Apparatus' license, then this would require a higher level of administration, which could include the assessment of license applications and payment of a license fee.

5.2.2 Assurance of compliance with standards

Standards are important for C-ITS so that equipment and services are fit for purpose, safety and mobility outcomes are optimised, and devices are interoperable. There is a large number of C-ITS standards emerging internationally, only some of which will be a priority for Australia to comply with (Austroads and DIRD, 2015).

New systems and processes will need to be established to determine type and level of assurance required for each standard. This will also involve decisions on whether industry is best placed to assure compliance, or whether some level of government involvement in the process is necessary.

For example, if a standard is referenced in a future regulatory instrument, such as an Australian Design Rule (ADR) for a vehicle safety application, or in the ACMA license conditions for a radio communications device, existing regulatory frameworks and associated systems will be leveraged to ensure compliance. Conversely, it is anticipated that a large number of standards could be complied with to an appropriate level without any regulatory requirements.

A recent independent review of C-ITS management options suggests that decisions on the level and type of standards certification should be decided on a case-by-case basis. The basis for decision-making would be the risk and consequences of non-compliance, ability to use existing systems to assure compliance, and the potential benefits of aligning with emerging international C-ITS schemes. This would require a framework to guide decisions on an appropriate compliance scheme for each standard.

It has been proposed that Austroads play a lead role in progressing a framework to guide decisions on which standards require compliance, and what level and type of compliance scheme may be required for each. This will be done in close collaboration with government and industry stakeholders.

Section 5.2.7 provides further information concerning standards.

5.2.3 Security and trust (Security Credential Management System)

Ensuring an appropriate level of security and trust for C-ITS, for both systems and data, will be one of the most significant challenges to address in the emerging C-ITS ecosystem. Consistency in the use of security systems is critical to enable authentication, integrity and confidentiality between different users, and to prevent cyber threats, malicious acts and defective messages (Austroads and DIRD, 2015).

The system that is emerging internationally to address these issues is commonly referred to as a Security Credential Management System (SCMS). The SCMS will be based on a Public Key Infrastructure (PKI), which involves a set of hardware, software and people, as well as the policies and procedures needed to create, manage, distribute, use, store, and revoke digital security certificates.

Ensuring an appropriate level of security and trust for C-ITS, for both systems and data, will be one of the most significant challenges to address in the emerging C-ITS ecosystem.

There is currently no SCMS that can be used to support the deployment of 5.9 GHz DSRC. However, work is being conducted internationally towards establishing a globally consistent SCMS, with which Australia will need to harmonise its C-ITS deployments. TCA is the Australian representative on an international harmonisation working group for C-ITS security.

In the long-term, the role of SCMS manager will be to oversee the whole SCMS for a region or jurisdiction. The manager provides administration, coordination, and technical direction, and ensures that all aspects of the SCMS is managed in accordance with agreed and harmonised rules. This hierarchical approach will be critical to ensuring that security certificates are issued, monitored and revoked in a consistent and secure manner.

The resourcing and funding of a SCMS has the potential to be significant. A recent independent review of C-ITS management options suggested that decisions about the role government would have within the SCMS and its funding contribution should be considered once an internationally harmonised model for a SCMS emerges.

It is proposed that Austroads continues to take a lead in progressing the system requirements and initial designs for a SCMS, in collaboration with TCA and international stakeholders. Once the emerging SCMS becomes clearer, an informed decision can be made about transitioning responsibilities to an appropriate entity to oversee development and deployment of the SCMS.

5.2.4 Privacy

The NTC (2013) notes that current ITS applications are effectively managed within existing privacy frameworks. The NTC does not believe that C-ITS warrants a comprehensive legislative privacy regime that determines the roles, responsibilities and personal information flows across private sector entities engaged in C-ITS activities.

The NTC (2013) recommends that a 'privacy-by-design' approach should be adopted as international best practice in the design and development of a new scheme that handles personal information. This should include the undertaking of Privacy Impact Assessments (PIAs) by key entities that have responsibility for personal information generated by C-ITS. These would include the system manager, certification authority, road agencies and service providers. This approach will ensure that the collection, use and disclosure of personal information is compliant with the *Privacy Act* 1988. Where appropriate, this should be supplemented with published guidelines to provide certainty for all C-ITS providers and consumers as to how personal information should be handled. Best efforts to develop

A 'privacy-by-design' approach should be adopted as international best practice in the design and development of a new scheme that handles personal information.

privacy solutions to protect personal information, including pseudo-anonymous C-ITS signals, will also reinforce community confidence that C-ITS systems will not breach surveillance laws.

In circumstances where C-ITS relies on emerging technologies such as DSRC, commercial arrangements should seek to ensure compliance with surveillance device laws so that consumers provide their consent to use their information for C-ITS purposes (e.g. by including consent in the terms and conditions when purchasing a vehicle or smartphone application). It is imperative that consumers are informed about the implications of their consent, and it should be included as part of any education or information campaign to promote the benefits of C-ITS.

It is not clear if the C-ITS system and operational environment will require exemptions from any of the Privacy Principles or attract businesses to sign up to the Privacy Code. In 2012, the Biometrics Institute Privacy Code was revoked by the Australian Information Commissioner at the request of the Biometrics Institute, in part due to a low level subscription to the code. Nonetheless, organisations should be encouraged to set clear and comprehensive privacy policies and the NTC (2013) would encourage participants to create a privacy code in order to establish common practices and to build consumer confidence in C-ITS handling of personal information.

NTC (2013) recommends that if individuals can be identified in some way via the data message broadcast by C-ITS, legislative provisions should be enacted to limit access to C-ITS information for enforcement purposes for the following reasons.

- C-ITS may be used to identify individuals in time and place.
- Enforcement activities are largely exempt from privacy principles and the *Surveillance Devices Act 2004* is likely to have limited restrictive impact on enforcement activities.
- C-ITS uptake is expected to be low if personal information is easily and widely accessed for enforcement purposes.

These provisions should set out the circumstances that police, or another enforcement agency, should seek an access warrant by court order to obtain C-ITS information, in addition to information sharing provisions. Legislation could also state in what circumstances a warrant is not required by an agency (e.g. for non-enforcement purposes, such as traffic management, provided appropriate safeguards are in place).

NTC (2013) has made the following recommendations:

- Austroads adopt privacy principles, including the undertaking of a Privacy Impact Assessment, in the development of the C-ITS operational framework.
- In developing and implementing a C-ITS operational framework, in particular for standards for the data message broadcast by C-ITS stations, the Australian Government seek the highest possible level of anonymity for drivers and that this be a key focus for Austroads in developing the C-ITS operational framework.
- Australian Ministers explicitly consider privacy impacts on drivers in any decision relating to institutional arrangements for C-ITS. In particular, any entity that manages and stores unique identifiers is separate from agencies that hold licensing and registration information.
- In the event that individuals can be reasonably identified from the safety data messages broadcast by C-ITS devices, that specific legislative be developed to define what circumstances organisations are exempt from compliance with privacy principles, including enforcement agencies that may access C-ITS personal information.

5.2.5 Vehicle positioning

Implementing C-ITS will require dedicated wireless communication technology, vehicle positioning data and enhanced digital road maps as the key components of C-ITS systems (Austroads, 2013b).

Emerging C-ITS applications require vehicle positioning accuracy to one of three levels, being road-level (metre), lane-level (sub-metre) and where-in-lane-level (decimetre).

Many emerging cooperative safety applications may require absolute positioning accuracy of one metre or better. This cannot be reliably achieved with standalone GNSS (Global Navigation Satellite System) and low cost receivers.

The emerging timeliness requirement for road-level applications is about one second (1 Hz), while for lane-level and where-in-lane-level applications it is 0.1 second (10 Hz). Other performance requirements for vehicle positioning systems, such as continuity, availability, integrity and interoperability, are also critical.

The key findings from Austroads (2013b) are as follows:

- Standalone GNSS with low cost receivers cannot meet the positioning requirements for all emerging C-ITS applications.
- C-ITS developments in Europe and the US have access to a higher level of positioning than what is provided through standalone GNSS as they are able to use SBAS (Space Based Augmented System) signals.
- Australia does not have access to an SBAS service.
- As Australia does not have access to a wide area augmented GNSS, such as an SBAS, it may not be able to deploy the same C-ITS applications used internationally when they may have a higher level of absolute positioning accuracy and integrity in mind.
- It is highly probable that a wide area augmentation service will be required for safety-related C-ITS applications to effectively operate in Australia.

Implementing C-ITS will require dedicated wireless communication technology, vehicle positioning data and enhanced digital road maps as the key components of C-ITS systems.

- As the C-ITS applications are still developing it is unknown what percentage will require a certain level of positioning accuracy, reliability, integrity etc. that a system such as an SBAS or other augmentation service can provide.
- As the C-ITS applications are still developing it is difficult to quantify whether urban areas will require higher level positioning data than country areas; however, where a C-ITS application is designed for use in both urban and country environments, the same standard of positioning data will be required for both areas.
- Any positioning service developed for Australia must be compatible with the global C-ITS platform, and comply with relevant international standards.

5.2.6 Digital mapping

Many of the safety critical C-ITS and ADAS applications require high accuracy digital mapping data. While various international standards exist for navigation, enhanced digital maps for C-ITS and ADAS are still emerging with further standards to be developed and architecture required (Austroads, 2013a).

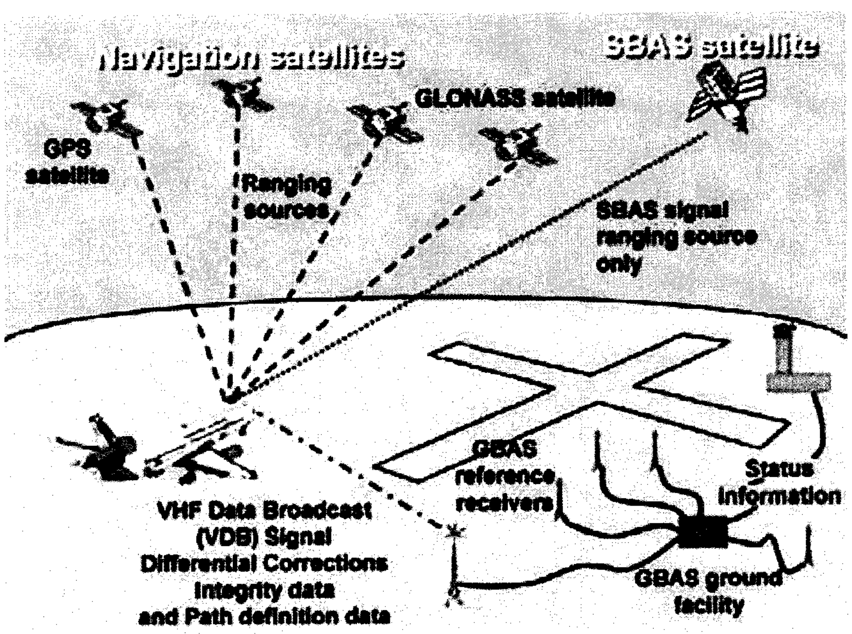

Figure 5.1 SBAS architecture (Source: IEEE)

The key findings from Austroads (2013a) are listed below, which include some major challenges to developing digital maps for C-ITS and ADAS in Australia and New Zealand.

Key findings:

- The requirements of map-enabled C-ITS and ADAS applications are very similar and will likely require the same digital map data and therefore should be considered together.
- Emerging safety-critical C-ITS and ADAS applications require high accuracy digital mapping data. The fourth generation enhanced maps to meet these requirements need further development, both in terms of standards and architecture.
- The current strategy for governments globally should be to provide leadership and partnerships with industry on international C-ITS programs to ensure a common direction for C-ITS development and deployment.
- Australia and New Zealand will largely adopt C-ITS applications from Europe, the US and other world regions at the forefront of C-ITS development.
- Australian and New Zealand governments should closely collaborate with industry, establish policy and regulatory frameworks and contribute to the development of international standards and processes that support the emerging digital mapping requirements of C-ITS.
- As the authoritative source of many road data attributes, Australia's and New Zealand's road transport authorities will remain key stakeholders in the road network data supply chain and will need to make changes to their data management processes to meet emerging map data requirements.

5.2.7 Standards

Austroads (2015b) reviewed over 160 standards from the key C-ITS developing regions of EU and the US. In this review Austroads identified a US scenario and an EU scenario for possible adoption by Australia and New Zealand. The outcomes of the assessment may be used to provide an understanding of the emerging standards and their respective scenarios. Table 5.1 provides an overview of this review, while Table 5.2 outlines the key differences between the scenarios based on the standards assessed.

The assessment identified that it may not be feasible to mix and match the standards from each scenario. Therefore, a decision on which scenario to align with is needed to harmonise with that scenario, to adopt standards associated with the scenario, to confirm the compliance level and type for each adopted standard, and to confirm whether compliance to the adopted standard is regulated or not.

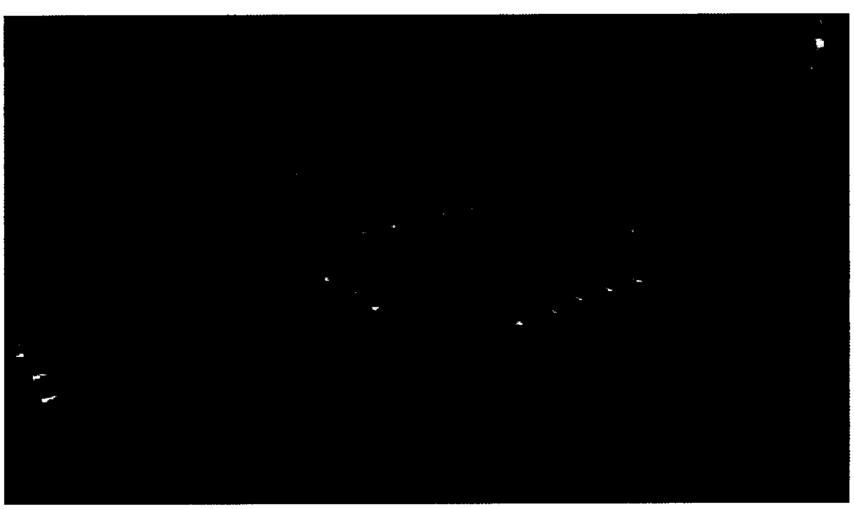

Figure 5.2 ADAS applications require high accuracy digital map data (Source: HERE)

Table 5.1 Overview of review of C-ITS standards undertaken by Austroads (2015b)

	EU scenario	US scenario
Standards developing organisations	ETSI (European Telecommunication Standard Institute), CEN/ISO (European Committee for Standardisation / International Standards Organisation)	SAE (Society of Automotive Engineers), IEEE (Institute of Electrical and Electronics Engineers), NTCIP (National Transportation Communications for ITS Protocol)
Number of standards	155	11
Number of high priority standards identified to adopt in Australia	55	7

Figure 5.3 A vehicle used for creating digital maps of road environment (Source: HERE)

Table 5.2 Differences between EU scenario and US scenario in relation to C-ITS standards (Source: Austroads, 2015b)

	EU Scenario	US scenario
Architecture and message types	Designing an open hybrid platform (based on a standardised ITS station) to manage multiple communications. ETSI component delivers the 5.9 GHz communications (similar to the US scenario). CEN/ ISO component focuses on developing a platform in which 5.9 GHz DSRC complies with other standardised communications.	Concentrates on using 5.9 GHz to enable safety-critical applications.
	Uses a Cooperative Awareness Message (CAM) and a Decentralised Environmental Notification Message (DENM)	Uses a Basic Safety Message (BSM).
5.9 GHz channel allocation	Utilises 70 MHz spectrum of the 5.9 GHz band (i.e. 5.855 to 5.925 GHz).	Proposing to utilise 50 MHz (i.e. 5.855 to 5.905 GHz).
	ETSI standard has a much stricter out-of-band emission limit than the US IEEE standard, although the European limit is currently being reviewed.	
		Does not consider coexistence of 5.9 GHz DSRC for use in C-ITS with 5.8 GHz DSRC for use in electronic fee collection.
	Considering dual radios which will enable the radio to simultaneously receive on both the control and service channels except while transmitting.	Proposing, for early deployments, a channel switching concept which results in the one radio switching between the control channel and service channels.
GeoNetworking/ multi-hop and local dynamic maps	Proposes to include GeoNetworking/multi-hop which enables a C-ITS device to receive and then re-broadcast a message to other devices within a defined geographic area.	Not requiring GeoNetworking/multi-hop. Does not refer to a local dynamic map but does have map messages as part of SAE J2735.
Security	Managed at the network layer in the EU scenario.	Managed at the application layer
	Has more infield deployment experience.	A more developed security architecture than the EU scenario. As a result the US scenario has a more developed approach to misbehaviour management and certificate revocation from an architecture perspective.
	The SCMS in the EU scenario does not provide anonymity in the PKI services. It does consider additional hardware security within the vehicle to establish additional levels of trust.	Has a SCMS that provides a greater level of privacy/ anonymity in the issuing and management of the PKI certificates.
	Proposes that all or almost all messages need to be verified.	Proposes that only messages which lead to a safety warning be verified.

Comments
Allocation of the control channel and the channels used for safety applications are different in the two scenarios. Australian and New Zealand spectrum regulators are considering initially allocating the same 50 MHz as Europe which would restrict the ability to fully harmonise with the US scenario. The same DSRC hardware is likely to be able to comply with both the US and EU scenario channel allocations, with some differences in the firmware or software.
A stricter out-of-band emission limit may require more expensive filters.
Regulators in both the US and EU are currently considering proposals to open up more of the 5 GHz band, including the 5.9 GHz band, to allow coexistence with unlicensed wireless local-area network (WLAN) equipment (e.g. Wi-Fi) which could have implications for C-ITS using 5.9 GHz DSRC.
There have been some concerns within the EU about implementing. GeoNetworking in real-life scenarios due to potential congestion of the 5.9 GHz spectrum.
Security certificate formats are not compatible between the EU and US.

5.2.8 US/EU/AU (Australia) harmonisation

The EU-US cooperation on ITS recognised the need to harmonise security policies and standards for C-ITS (USDOT, 2014b). This led to the formation of the Harmonisation Task Group # 6 (HTG6), on which TCA is a co-lead. HTG6 intent is to identify where harmonisation is desirable by exploring the advantages and limitations of global versus local security policy alternatives including economic benefits.

Work by HTG6 has identified five service areas that require systemic and institutional harmonisation as a priority (TCA, 2015):

- specialised PKI services for C-ITS referred to as a Cooperative Credential Management System (CCMS)
- management of these specialised PKI services
- certification and approvals including vetting of organisation to do same
- auditing
- initialisation processes for C-ITS devices (commonly referred to as 'bootstrapping').

TCA (2015) claims that the above service areas are essential for delivering the three core functions for operational C-ITS in Australia as outlined in Section 5.1.

Building upon the outcomes of HTG6, HTG7 is being proposed to assess and recommend standards to support global C-ITS deployments including recommendations for the management of globally unique C-ITS identifiers. The standards assessment undertaken by Austroads (Austroads, 2015b) will feed into HTG7.

HGT7 will also develop mechanisms to ensure that C-ITS device identifiers (both in vehicles and on the roadside) are globally unique, which is essential for interoperability of C-ITS products and services.

5.2.9 Roles and responsibilities for C-ITS

The ISO technical standard for the roles and responsibilities required to deploy and operate C-ITS identified four high level categories of roles as illustrated in Figure 6.1 (ISO, 2014, cited in Austroads, 2015a).

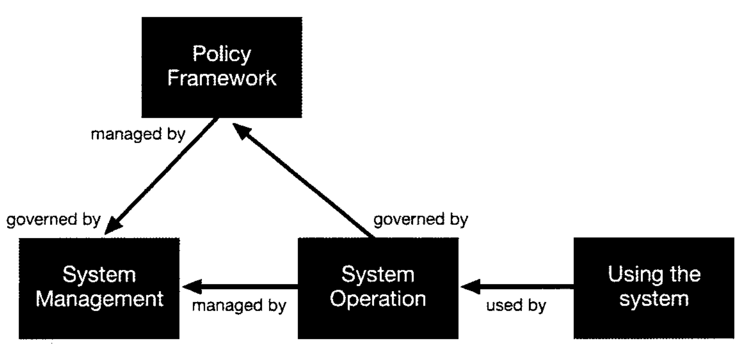

Figure 5.3 High-level description of organisational roles for C-ITS (Source: ISO/TS17427:2014)

This categorisation of roles will be used in various sections of the document. Austroads (2015a) provides a brief description for each of the roles as follows:

Policy framework
(Responsible for all governing and institutional activities in the system)

- Define the regulatory and non-regulatory policies relevant to C-ITS.
- Define the standards and guidelines relevant to C-ITS.
- Ensure standards, guidelines, laws and regulations are followed and applied.

System management
(Responsible for the management activities within the system and governed by the policy framework role)

- Designs, tests and deploys C-ITS.
- Manages maintenance and support services for C-ITS.
- Manages availability and capacity of C-ITS.
- Manages access, security, confidentiality and integrity for C-ITS.
- Manages configuration, changes, and updates for C-ITS.
- Enables communications within and between C-ITS devices.
- Maintains the implemented C-ITS architecture.

System operation
(Responsible for activities related to the operation of the system and supported by the system management role)

- Provides content, which could include any type of data.
- Provides services, which include processing content to create the end service.
- Presents service results to the end user.

End user
(Responsible for requesting, receiving and using the end C-ITS application or service, which in some use cases may be imposed by the jurisdiction, insurer or a third party contracted to provide a service to the recipient).

- Issues a service request, and fulfilling any obligations (e.g. subscription conditions).
- Recognises service result presentation (which could be visual, audible, etc.).
- Judges the need to react, and reacts accordingly.

There is a range of government and industry entities that are likely to play a role in overseeing, managing and/or supporting the operations of C-ITS.

5.3 Other issues which are no different to any other transport technology introduced

5.3.1 Liability

Although it is expected that in a widely adopted C-ITS environment, the number of crashes would be reduced significantly, cashes could still occur due to technology failure, limitations of technology or problems in the interaction of humans and technology. C-ITS applications draw together multiple parties, who would be involved in providing a service through C-ITS, including road agencies, drivers, vehicle manufacturers, as well as technology and communication companies. As technology advances and becomes more integrated, attributing liability in the event of a crash can potentially become more complex, particularly when many players are involved.

So far, ADAS such as lane departure warning, crash avoidance and speed advisory systems, have been introduced within pre-existing frameworks without increased litigation for vehicle manufacturers (NTC, 2013). Tort law, contract law and product liability, including consumer protection laws, together provide the required level of certainty for manufacturers, road agencies, service providers and consumers that responsibility for wrongdoing can be appropriately assigned. Any changes would have to be made with extreme care, in order not to disturb the appropriate allocation of risks between parties, nor adversely affect the balance between innovation and safety.

Research and stakeholder consultation undertaken by NTC indicates that liability has not been a significant hindrance to the development of new transport technologies in the past. Existing liability frameworks should suffice for C-ITS that facilitates warning and driver assistance applications. However, a further review would be required to assess the potential liability issues if C-ITS was to enable AVs (NTC, 2013).

5.3.2 Driver distraction

C-ITS applications are one of a wide range of technologies that are present in today's vehicles, and driver distraction is an issue that is broader than C-ITS and must be addressed in a holistic way (NTC, 2013). However, C-ITS applications do add weight to the need for governments to look more closely at distraction issues.

In the event that international standards are adopted by the market, governments may have a minimal role regulating driver distraction in addition to ADRs and Australian Road Rules. Although, consideration should be given to a government contribution to the development of industry guidelines or code that formalises the commitment to agreed international standards.

Certification provides additional certainty of standards and compliance on a case-by-case basis, but also has cost implications and could potentially impact innovation compared to rule-based self-regulatory approaches.

The recently recommended change to the Australian Road Rules to allow a mobile phone to be used as a driver's aid will go some way to ensuring a technology neutral approach that would conceivably include C-ITS applications. It may still leave some differences in the way that a driver can interact with a mobile phone that is being used as a driver's aid, as opposed to a stand-alone device. The Australian Road Rules may require further examination as C-ITS technology continues to evolve.

NTC considers that current rules around distraction should not present a barrier to the deployment of C-ITS technology. It has recommended that the distraction issues raised by this technology should be considered as part of any broader review of driver distraction rather than in isolation.

5.4 Trials

5.4.1 CITI Project

The Cooperative Intelligent Transport Initiative (CITI) will establish an integrated test-bed in the Illawarra region of New South Wales to facilitate the testing, measurement and assessment of C-ITS along a 42 km freight corridor connecting Hume Highway to Port Kembla. This will be one of the first large-scale test facilities dedicated to heavy goods vehicles in the world.

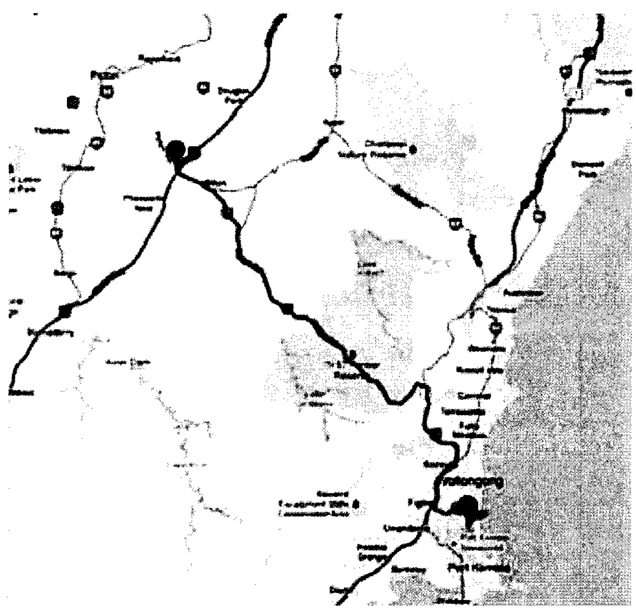

Figure 5.4 Location of CITI project (Source: Transport for NSW)

The first phase of the initiative, to be completed in 2015, will include up to 60 heavy vehicles being fitted with DSRC transceivers and in-cabin displays. A roadside transmission station will broadcast speed limit information to heavy vehicles descending the steep Mount Ousley pass. This section of road has a special 40 km/h truck and bus speed limit applied to seven kilometres of its descent information. Three intersections will also be equipped with DSRC roadside units to provide real-time Signal Phase and Timing (SPaT) information.

Drivers in participating vehicles will receive a range of safety and network related messages including intersection collision, heavy braking ahead, forward and speed zone warnings as well as traffic signal phase information. The initiative also involves establishing a data collection and storage system.

The test-bed will provide a place for ITS researchers to conduct testing, research and development in an Australian C-ITS environment. In the second phase of the initiative, data analysis will be undertaken and the test-bed will be expanded to include the installation of C-ITS technology into more vehicles, further roadside infrastructure and the testing of other applications such as breakdown alerts or weather warnings.

The project differs from others around the world in that it is planned to be available to ITS researchers for up to five years, whereas most other demonstration sites have only been established for up to 18 months and access to the site has been restricted to one or two organisations (Wall, 2013).

Figure 5.5 CITI project – Heavy vehicles will be fitted with DSRC transceivers (Source: Transport for NSW)

5.4.2 Smart Rest Areas

Transport for NSW will trial 'Smart Rest Areas' along the Newell Highway between Narrabri and Gilgandra (approximately 210 km) to improve safety for heavy vehicle drivers using C-ITS technology (TfNSW, 2014).

Cellular technology will be used to provide truck drivers with real-time information about the location of heavy vehicle areas, distance and estimated travel time to rest areas, and vacancy details at the rest areas.

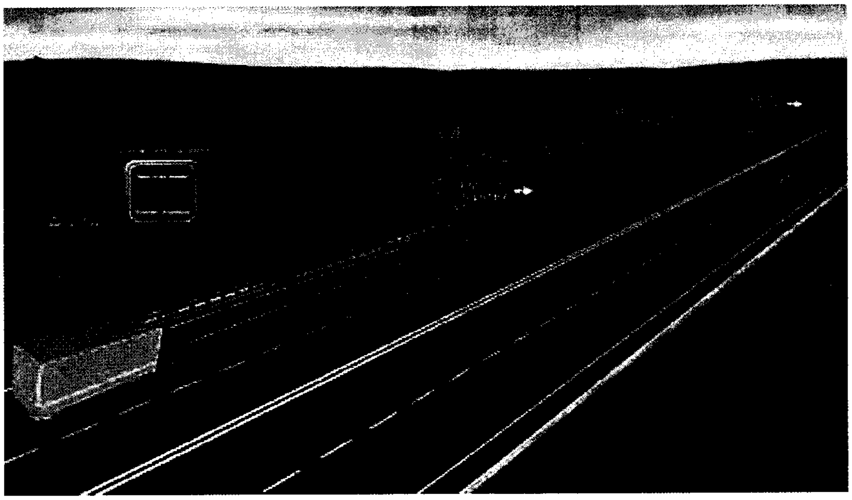

Figure 5.6 Smart Rest Areas trial will provide alerts to heavy vehicle drivers on rest area availability (Source: Transport for NSW)

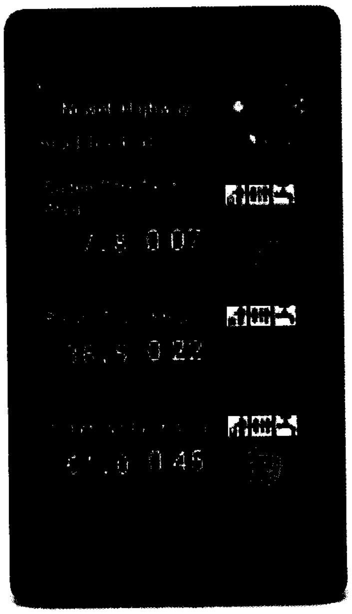

Figure 5.7 In-vehicle app that will provide heavy vehicle drivers with real-time information on up-coming rest areas (Source: Spatial Vision)

5.4.3 Rail Crossing Safety

AUD 5.5 million trial to improve safety at rail crossings has been completed. The trial used DSRC to establish wireless communication between trains approaching a level crossing and vehicles approaching the crossing. The three-year trial, believed to be a world-first, provides in-vehicle audible, visual and tactile warnings for vehicles in time to avoid a collision with approaching trains if the system detects the possibility. The proof-of-concept trial was administered by the Automotive Cooperative Research Centre (AutoCRC), a Federal Government innovation funding authority. The research, system development and field trials were carried out by the La Trobe University's Centre for Technology Infusion (CTI) (PTV, n.d.).

Undertaken in three stages, the first stage included developing a simulator for level crossings. In the second stage a demonstration trial involving three vehicles fitted with the technology calibrated results from the simulator using real-world data. The third stage involved a full field trial at three level crossings involving eight trains and approximately 100 vehicles (cars, trucks and trains) to verify the full operation of the system in a live environment and to prove that it is ready for wider implementation.

The demonstration trial also incorporated the development of the human-machine interface to deliver audible and visual warnings to the road vehicle drivers through a GPS navigation style screen based on human behaviour research.

The field trials were designed to test the system for both active level crossings (those with train activated warnings such as flashing lights and boom gates) and passive level crossings (those with only stop or give way signs) in both country and metropolitan areas.

The trials were designed to test the effectiveness of the technology and also drivers' reactions to different messages. The system delivers three levels of warning, graduating in urgency and volume. The first advises 'there is a crossing ahead', the second is similar to the conventional flashing light warning indicating 'there is a train in the vicinity' and finally, when a collision is imminent and requires emergency action, an imperative 'STOP - you are about to collide with a train!' warning is emitted.

Trial scenarios aimed to test for and minimise 'false positive' warnings such as a warning being provided when a vehicle has passed the crossing, or when approaching the railway on a path which will not cross it.

Following the three Victorian trials, the Queensland Government has also implemented trials involving a larger number of trains over a six-month period (ITS International, 2013).

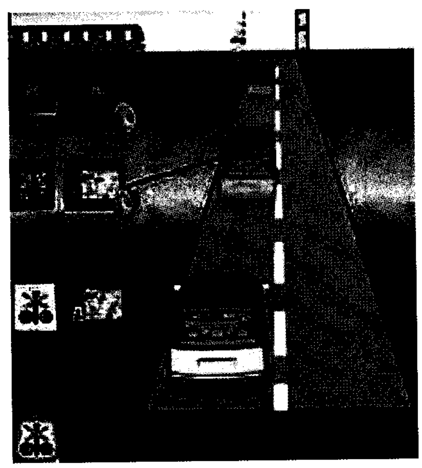

Figure 5.8 The system delivers three levels of warning graduating in urgency and volume

6. Deployment timelines

Different CV technologies are likely to have different deployment timeframes. This section will focus on the likely deployment timeframes for C-ITS equipped vehicles, with their main benefit being safety.

Figure 6.1 provides estimates for the uptake of C-ITS equipped vehicles in the US under three scenarios.

The US is progressing a proposed rule-making that would mandate C-ITS in new light vehicles. However, Australia currently does not plan to mandate C-ITS fitment in vehicles. Therefore, it is appropriate to consider the 15-year organic adoption curve. If 2017 represents Year 1 for Australia, then Table 6.1 outlines the likely proportions of C-ITS equipped vehicles over time, assuming a similar uptake rate for organic adoption in the US and no aftermarket fitment. Given the lower Australian vehicle turnover the proportions in Table 6.1 are provided as a range with a lower limit than the US estimates.

In the years beyond 2020, it is likely that AVs will start to appear on Australian roads. AVs will significantly change transport services, opening up new possibilities for personal and shared transport from point A to B that does not rely on owning a car. If the options for transport using AVs become popular, the proportion of travel on roads by C-ITS equipped vehicles will be higher than the estimates provided above.

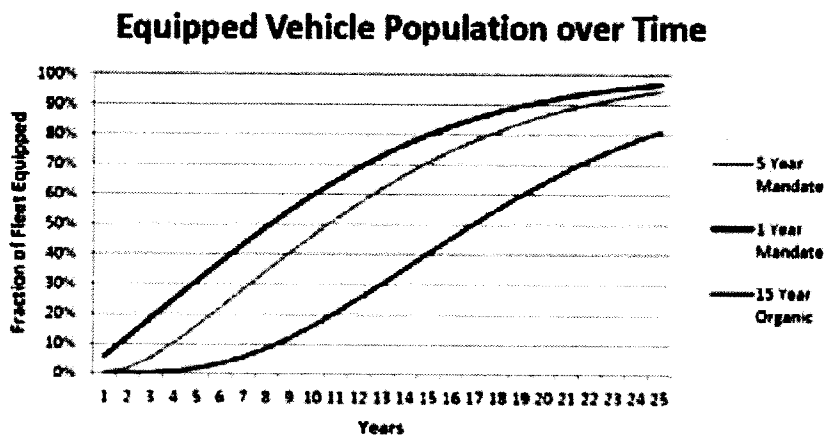

Figure 6.1 C-ITS equipped vehicle adoption rate estimates for the US (Source: USDOT, 2014a)

Table 6.1 Estimated proportion of vehicle fleet equipped for C-ITS in Australia under a 15-year organic adoption scenario (based on USDOT, 2014a).

Year	Estimate of proportion of vehicle fleet likely to be equipped for C-ITS in Australia
2017	Very few
2022	0-5%
2027	10-15%
2032	30-40%
2037	50-65%

7. What we may need to do

The initial deployment of C-ITS will require a targeted list of day-one applications that deliver value to customers. These will need defined roles and responsibilities, roll-out plans, defined hot spot areas, investment plans and related business cases (ERTICO, 2015). It is important to agree on a set of non-complex applications that are easy to implement with limited costs, but at the same time achieve high levels of customer benefit.

The list of day-one applications agreed in Europe is indicated in Table 7.1. It is likely a subset of these day-one applications will be adopted in Australia.

The day-one applications are not linked to specific communication technologies. However, these applications have different operational requirements such as low latency that would lead to using specific communication technologies. There are several access technologies that could be used for C-ITS applications, and it is expected that new technologies will emerge on a regular basis. At present there are four main radio communication technologies that are available:

- FM/DAB+ radio broadcast
- mobile broadband (3G/4G/5G cellular networks)
- 5.9 GHz DSRC
- satellite.

Access to multiple communication technologies to support service provision, particularly in regional WA is essential to be able to achieve the best outcomes in relation to costs, reliability and safety.

It is also important that the use applications are based on standardised message sets and have been tested and validated in field operational tests.

Table 7.1 Day-one C-ITS applications for Europe

	Agreed day-one applications for Europe
1.	Hazard location warning
2.	Slow vehicle warning
3.	Traffic jam ahead warning
4.	Road works warning
5.	Stationary vehicle warning
6.	In vehicle signage
7.	Probe vehicle data
8.	Signal phase and timing
9.	Emergency vehicle warning
10.	Emergency brake light
11.	Motorcycle approaching indicator

Access to multiple communication technologies to support service provision, particularly in regional WA is essential to be able to achieve the best outcomes in relation to costs, reliability and safety.

What Main Roads may need to do to support these day-one use applications and the initial C-ITS deployment is still emerging through the work being undertaken nationally, led by Austroads.

It appears that in Australia the preferred approach will be to put in place the policy, legal and regulatory frameworks to support C-ITS by addressing key deployment challenges. In particular, spectrum management and device licensing, assurance and compliance with standards, and security and trust as discussed in Chapter 5 through the work led by Austroads, leaving it largely to the market to deploy C-ITS with supporting roadside infrastructure provided by the respective road agencies at jurisdiction level.

However, roadside infrastructure requirements will depend on what technology is used for communications, which will largely be determined by market forces and interests. Main Roads' interest would be to support applications that deliver significant safety, efficiency and environmental benefits for its customers, based on cost/benefit analysis of investment needed in roadside infrastructure and back-office systems. At present, we need more guidance nationally as to when, where and how we need to make such investment.

Main Roads' ITC controlled systems such as STREAMS and SCATS need to be integrated and updated to support day-one C-ITS applications.

7.1 Alternative scenarios for Main Roads for deployment of roadside infrastructure

Until what is expected of road agencies becomes clear, there are two possible alternative positions for Main Roads regarding the roadside infrastructure required for C-ITS, while completing data management/access and system integration in sync with other jurisdictions:

a) Do not deploy RSUs and instead wait for communication options such as 4G and 5G mobile communications and satellite communications to emerge.

b) Deploy limited RSUs in critical corridors and hot spots such as rail crossings with a poor safety record.

Scenario (a) still provides access to the opportunities of CVs but it may take longer to allow communications technology to mature. While 5G communications are still in development, the specifications advanced by the industry body GSM (Groupe Speciale Mobile) Alliance shows a step-change above current 4G technology (GSMA Intelligence, 2014):

- 1-10 Gbps connections to end points in the field (i.e. not theoretical maximum)
- 1 millisecond (ms) end-to-end round trip delay (latency)
- 1000 x bandwidth per unit area
- 10-100 x number of connected devices
- (Perception of) 99.999 percent availability
- (Perception of) 100 percent coverage
- 90 percent reduction in network energy usage
- up to ten year battery life for low power, machine-type devices

Achieving 1 ms latency would require telecommunications providers to have a dense network of access points with many points of interconnection between providers. It is not yet certain that telecommunication providers will make substantial investments in infrastructure to achieve these 5G specifications. However, if they did, at face value 5G communications appears to be suitable for many CVs and C-ITS applications. Whether 5G, and in fact 4G/LTE Unlicensed or 4G/LTE Direct lives up to its promise is yet to be seen.

The commercial proposition for telecommunication providers to create the necessary 5G infrastructure may depend partly upon its use for CV applications, including streaming map data to enable self-driving functions. There is not a full overlap of candidate applications between 5G and DSRC, but some overlap does exist. A key point of difference is the nature of the access to the communications service – access to DSRC is likely to be nearly free once the equipment has been acquired, while access to 5G would likely require an ongoing subscription.

Scenario (b) involves deploying limited RSUs along selected critical corridors such as high-volume roads and hot spots. At this time it remains unclear what technology would be dominant for V2I communications once 5G is a realistic option. Therefore, it may not be advisable for us to deploy RSUs on a network-wide basis but there remains a case for limited deployment such as for a test corridor. A commitment to install RSUs on new roads (eg. Perth Freight Link and NorthLink due to open in 2019) would also provide greater certainty to encourage private investment.

Until what is expected of road agencies becomes clear, there are two possible scenarios for Main Roads to take regarding the roadside infrastructure required for C-ITS, while completing data management/access and system integration in sync with other jurisdictions.

7.2 How many RSUs should be deployed?

Realising C-ITS benefits is assisted by road authorities installing RSUs but is not entirely dependent on it. Therefore the case for deploying RSUs should be subject to staged installation with additional benefits being relative to additional costs. The ongoing subscription nature of 4G or 5G communications means that the entire cost of installing roadside infrastructure should not be considered an additional cost, rather only that part that exceeds the subscription costs.

In examining the question of how many RSUs should be deployed, USDOT (2014a) extensively reviewed anticipated CV applications. An initial list of nearly 100 mobility, safety, environmental and agency-focused CV applications was created. Since the scope of this effort is focused on infrastructure, only the applications that require CV field infrastructure were considered (V2V applications were not included in the analysis).

The assessment by USDOT (2014a) is that for signalised intersections, the costs of installation are likely to be warranted by the benefits at around 80 percent of signalised intersections. Converting to an Australian environment, the full estimated installation costs per site appear to be around AUD 30-40 000 including design and traffic management, with maintenance and operation costs in the order of AUD 4-5 000 per year.

The case for deploying RSUs should be subject to incremental consideration with additional benefits being relative to additional costs.

Table 7.1 Estimated cost of C-ITS deployment at signalised intersections

Proportion of signalised intersection deployment %	Number of sites (in WA)	Total cost
20	220 sites, highest-volume intersections, potentially affect 50% of intersection crashes	AUD 6.6-8.8M upfront AUD 0.9-1.1M ongoing
50	550 sites, half of all intersections; potentially affect 80% of intersection crashes	AUD 16.5-22M upfront AUD 2.2-2.8M ongoing
80	880 sites, all intersections where warranted	AUD 26-35M upfront AUD 3.5-4.4M ongoing

USDOT (2014a) assessed the likely percentage of non-intersection sites, (such as freeway Vehicle Detection Station sites) where installation would be warranted less at 50 percent.

It is likely RSUs will be installed incrementally, starting with the highest priority sites, as well as new installations. Therefore, instead of viewing the deployment scenarios outlined by USDOT (2014a) as alternatives, they are better considered as progressive stages.

For the foreseeable future, assuming prioritised installation, the investment required in roadside infrastructure for C-ITS is likely to be only moderate. A commitment of AUD 15 million would allow the roll-out of roadside infrastructure to the highest priority locations, as well as investment in supporting traffic management control systems so that they can take advantage of C-ITS opportunities. By way of comparison, WA is currently investing AUD 36 million to roll out electronic speed limit signs at schools across the state (WA Government, 2013) as another ITS-enabled road safety initiative.

7.3 Traffic management and traveller information systems and devices – readiness for C-ITS

For Main Roads to take advantage of V2I, its current traffic management and control systems need to make use of the new data acquired and issue the required alerts and information. The issue of readiness for other ITS to interact with C-ITS was explored by Austroads in the C-ITS Interoperability with Existing ITS Infrastructure (Austroads, 2014a) report.

In early deployment of C-ITS, only a small proportion of the vehicle fleet will be equipped, meaning that most day-one applications will be V2I focussed.

Main Roads' current control systems such as STREAMS and SCATS do not provide the functionality required to take advantage of these V2I applications. In some cases the changes required to these and other systems will be small, however in other cases more fundamental changes may be required. Main Roads' ITS Master Plan recognised the need for system changes, including the action to expand ITS control system functions to allow for benefits from cooperative and multimodal systems (Main Roads, 2014). Further scoping is required to identify higher priority gaps to be addressed for Western Australia.

7.4 Data management and access processes

In sync with other jurisdictions, Main Roads need to ensure that data management and access processes in relation to road agency data such as speed zone, SPaT, intersection geometry and roadworks are improved and aligned to support and facilitate emerging C-ITS applications. Typically, road agencies are the authoritative sources of such data.

7.5 Future proofing existing and new ITS

We will also need to ensure that new and upgraded ITS devices provide the functions required to support future V2I based applications. This includes VMS, LUMS and ESL, in addition to traffic signals.

7.6 Transition to National ITS Architecture

Realising the full potential of C-ITS will need to be supported with a common ITS architecture across jurisdictions. Austroads has proposed a National ITS Architecture (NITSA) based on European FRAME Architecture (Austroads, 2014b). Therefore, Main Roads should continue to transition to NITSA, starting with any new ITS deployments and progressively replacing legacy systems with new systems that comply with NITSA. This should occur when they are to be renewed or replaced, and the transition to NITSA is economically justified.

7.7 Development of in-house skills and capability

The adoption of Automated and Connected vehicles will change Main Roads service delivery environment and require enhanced skills and capabilities to deliver these services. Areas of focus for capability development include ITS architecture, systems engineering and Big Data analytics. Together these will support the planning and deployment of supporting infrastructure for C-ITS, as well as transition to NITSA.

7.8 Trials for testing readiness

Practical experience will be invaluable for increasing Main Roads' readiness to manage the new environment featuring Automated and Connected vehicles. Pilot programs, demonstrations and test-beds would allow Main Roads staff to learn about the implications of the new technology directly and build the knowledge base, processes and connections needed for the future.

Main Roads has the opportunity to take advantage of strong research and development activities being undertaken at local universities, and within some specialist local industries that are at the cutting edge of the development of CVs and AVs internationally. A locally established test-bed would also enable readiness trials of CV applications under local conditions, while also being used to undertake research and development for any WA-specific issues in the deployment of CVs and AVs.

7 .9 Continued national engagement

It is important that Main Roads continues to engage in the national work underway for C-ITS through Austroads and other relevant forums. Any action taken at jurisdiction level needs to be consistent and coordinated with other jurisdictions. Also, at this critical period, we need to remain well informed of what's happening nationally and internationally.

Main Roads has the opportunity to take advantage of strong research and development activities being undertaken at local universities, and within some specialist local industries that are at the cutting edge of the development of CVs and AVs internationally.

8. Concluding remarks and recommendations

Vehicles with C-ITS capabilities are likely to be available in Australia from 2017. Austroads is taking a lead role in identifying, implementing and coordinating the groundwork required to enable operation of C-ITS capable vehicles in Australia.

The other aspects of CVs such as infotainment, traveller information and navigation, and remote diagnostics, maintenance and software updates are largely being driven through collaboration between vehicle manufacturers and technology companies. The deployment of such applications will occur largely independently of road agencies.

The key driver for C-ITS is significant road safety benefits, with an estimated 25-35 percent reduction in serious casualty crashes likely, once V2X equipped vehicles achieve saturation of the vehicle fleet.

The adoption rate of C-ITS equipped vehicles will depend, in part, on whether V2X communication capability becomes mandatory for new vehicles. Without such regulations, by 2027 only around 10-15 percent of the vehicle fleet is likely to be equipped. However, the concurrent rise of vehicle automation and a move towards shared fleets rather than individual ownership may mean the proportion of vehicle kilometres travelled by equipped vehicles will be much higher than this.

Access to multiple communication technologies to support service provision, particularly in regional WA is essential to be able to achieve the best outcomes in relation to costs, reliability and safety.

It is also important that the use applications are based on standardised message sets and have been tested and validated in field operational tests.

What we as a road agency may need to do to support C-ITS enabled vehicles to operate on our road network, will fully emerge through the Austroads led work being undertaken nationally.

It appears that in Australia, the preferred approach would be to put in place the policy, legal and regulatory frameworks to support C-ITS by addressing the key deployment challenges. In particular, spectrum management and device licensing, assurance and compliance with standards, and security and trust as discussed in Chapter 5 through the work led by Austroads, leaving it largely to the market to deploy C-ITS, with any supporting roadside infrastructure provided by the respective road agencies at jurisdiction level.

However, roadside infrastructure requirements will be defined by what technology may be used for communications, which will largely be driven by commercial market forces and interests. From a road agency point of view, Main Roads' interest will be to support applications that deliver significant safety, efficiency and environmental benefits for their customers, based on cost/benefit analysis for investment needed in roadside infrastructure and back-office systems. At present, we need more guidance nationally as to when, where and how we need to make such investments.

Main Roads' ITS control systems such as STREAMS and SCATS need to be integrated and updated to support day-one C-ITS applications.

Until what is expected of road agencies becomes clear, there are two alternative positions for Main Roads to take regarding the roadside infrastructure required for C-ITS, while completing data management/access and system integration in sync with other jurisdictions:

a) Do not deploy RSUs and instead wait for communication options such as 4G and 5G mobile communications, and satellite communications to emerge.

b) Deploy limited RSUs in critical corridors and hot spots such as rail crossings with poor safety records.

Although there is some promise that commercial 5G communications will meet many of the needs of Connected Vehicles, unlike DSRC this has not been proven in large scale pilot deployments. In the early days, targeted deployment of DSRC RSUs for V2I communications will provide clear benefits to car purchasers for this safety technology and encourage more rapid adoption.

For the foreseeable future, assuming a prioritised incremental installation, the investment required in roadside infrastructure for C-ITS is likely to be only moderate. A commitment of AUD 15 million would allow the roll-out of roadside infrastructure to the highest priority locations as well investment in the supporting traffic management control systems so that they can take advantage of C-ITS opportunities. The benefits of such moderate investments are likely to outweigh costs although the benefits case is partly reliant on this RSU deployment encouraging more rapid adoption of Connected Vehicle safety technologies in the future.

In Summary the following action plan is recommended for the next two to three years, until what's required in relation to C-ITS emerges and informs road agencies.

1. Continue participating in the current Austroads' led national policy and regulatory processes.
2. Identify and implement the changes required in STREAMS and SCATS to support day-one C-ITS applications.
3. Ensure data management and data access processes in relation to road agency data such as speed zone, SPaT, intersection geometry and roadworks, are improved and aligned to support and facilitate emerging C-ITS applications.
4. Identify and implement the communication changes required for existing and new ITS to future proof them for C-ITS applications.
5. Continue to facilitate the transition to the National ITS Architecture.
6. Develop in-house capabilities, particularly in ITS architecture and systems engineering, and exploit Big Data from CVs.
7. In partnership with academia and industry establish a local test-bed to examine readiness of C-ITS applications, and undertake research and development activities for WA specific issues in the deployment of CVs and AVs.
8. Commit to deploying RSUs on new and upgraded roads due to open beyond 2017, such as Perth Freight Link and NorthLink, and hot spots such as rail crossings with poor safety records.

References

AAMI (Australian Associated Motor Insurance Limited) (2015), "The AAMI Safe Driver App™ Safe driving you can track" http://www.aami.com.au/safe-driver-smartphone-app accessed 24 April 2015.

AASHTO (American Association of State Highway and Transportation Officials) (2013), "National Connected Vehicle Field Infrastructure Footprint Analysis

Applications Analysis", http://ssom.transportation.org/Documents/Applications_Analysis%20v3%20july%202013.pdf, accessed 17 April 2015.

ACMA (Australian Communications and Media Authority) (2009), "Planning for Intelligent Transport Systems", Proposal for the Introduction of Intelligent Transport Systems into the 5.9 GHz Band in Australia, ACMA, Melbourne.

Alfayate, M (2014), "European Policy for C-ITS Towards Connected Mobility", www.unece.org/fileadmin/DAM/trans/events/2014/Joint_BELGIUM-UNECE_ITS/10_ITS_Nov2014_Maria_Alfayate__European_Commission.pdf, accessed on 29 April 2015.

Amsterdam Group (2013), "Roadmap between Automotive Industry and Infrastructure Organisations on Initial Deployment of Cooperative ITS in Europe Version 1.0 http://amsterdamgroup.mett.nl/Downloads/downloads_getfilem.aspx?id=312793, accessed 29 April 2015.

Austroads (2011), *Evaluation of the Potential Safety Benefits of Collision Avoidance Technologies Through Vehicle to Vehicle Dedicated Short Range Communications (DSRC) in Australia*, Austroads Research Report AP–R375/11, Austroads, Sydney.

Austroads (2012a), *Cooperative ITS Strategic Plan*, Austroads Research Report AP-R413-12, Austroads, Sydney.

Austroads (2012b), *C-ITS 5.9 GHz Spectrum Management and Device Licensing Regime Report*, Austroads Research Report AP-R414-12, Austroads, Sydney.

Austroads (2013a), *Emerging Digital Mapping Requirements for C-ITS*, Austroads Research Report AP-R432-13, Austroads, Sydney.

Austroads (2013b), *Vehicle Positioning for C-ITS in Australia (Background Document)*, Austroads Research Report AP-R431-13, Austroads, Sydney.

Austroads (2014a), *C-ITS Interoperability with Existing ITS Infrastructure*, Austroads Research Report AP-R458-14, Austroads, Sydney.

Austroads (2014b), *National ITS Architecture Context and Vision*, Austroads Research Report AP-R467-14, Austroads, Sydney

Austroads (2015a), *Concept of Operations for C-ITS Core Functions*, Austroads Research Report AP-R479-15, Austroads, Sydney.

Austroads (2015b), *Cooperative Intelligent Transport Systems (C-ITS) Standards Assessment*, Austroads Research Report AP-R474-15, Austroads, Sydney.

Austroads and DIRD (Australian Federal Department of Infrastructure and Regional Development) (2015), "Cooperative Intelligent Transport Systems Agenda Paper", TISOC 15/23, Members Only Document, Main Roads' internal document management system TRIM D15#152210, accessed 8 April 2015.

Blervaque, V. (2014), "Connected Vehicles Status of C-ITS Deployment in Europe", presentation at workshop on Connected and Automated Driving Systems, 17-18 November 2014, Tokyo. http://www.sip-adus.jp/mwg-internal/de5fs23hu73ds/progress?id=kKqS0-D652mNZVYh0tsbOeLnLbtwNYPYfa5JHrv1e8U, accessed 19 May 2015.

Connected Signals (2015), "Connected Signals' Technology", http://connectedsignals.com/enlighten_tech.php, accessed 28 April 2015.

ERTICO (2010a), "ADASIS Forum: Advancing Map-enhanced Driver Assistance Systems", www.ertico.com/adasisforum, accessed 20 April 2012.

ERTICO (2010b), "About ROSATTE", www.ertico.com/about-rosatte/, accessed on 20 April 2012.

ERTICO (2015), "Communication Technologies for Future C-ITS Service Scenarios", Version 1.1. dated 27 March 2015, http://www.erticonetwork.com/ertico-news/entry/3683-ertico-releases-guide-about-technologies-for-future-c-its-service-scenarios, accessed 12 May 2015.

ETSI (European Telecommunications Standards Institute) (2010), "Intelligent Transport Systems (ITS): Vehicular Communications: Basic Set of Applications: Part 1: Functional Requirements", ETSI TS 102 637-1 V1.1.1 (2010-09), Sophia Antipolis, ETSI, France.

EU (European Commission) (2013), "eCall: Automated Emergency Call for Road Accidents Mandatory in Cars from 2015", http://europa.eu/rapid/press-release_IP-13-534_en.htm, accessed April 2015.

Faber, F., S. Ballingall, M. Burke and J. Williams, (2014), "Policy Implications of C-ITS Core Functions", paper presented at 2014 AITPM Conference, www.aitpm.com.au/articleDocuments/, accessed 9 April 2014.

GovTrack (2015), "S. 424: Wi-Fi Innovation Act", www.govtrack.us/congress/bills/114/s424, accessed 28 April 2015.

GSMA (Groupe Speciale Mobile Association) Intelligence (2014), "Understanding 5G: Perspectives on Future Technological Advancements in Mobile, http://www.gsma.com/network2020/volte/understanding-5g-perspectives-on-future-technological-advancements-in-mobile-gsmai-report-3/, accessed 17 April 2015.

ITS International (2013), "University Develops Rail Crossing Technology", http://www.itsinternational.com/categories/networking-communication-systems/news/university-develops-rail-crossing-safety-technology/, accessed 17 April 2015.

Jandrisits, M (2013) "Amsterdam Group Turn ITS Theory into Practice", ITS International, July/August 2013, www.itsinternational.com/categories/utc/features/amsterdam-group-turn-its-theory-into-practice/, accessed on 29 April 2015.

Main Roads (Main Roads Western Australia) (2014), "Intelligent Transport Systems Master Plan", http://trimwebdrawer/webdrawer/webdrawer.dll/webdrawer/rec/6117475/view, accessed 7 April 2015.

Main Roads (2015a), *Automated Vehicles: Are We Ready?*, Internal Report on Potential Implications for Main Roads WA, Main Roads Western Australia, Perth.

Main Roads (2015b), "Keeping WA Moving", Strategic Direction for Main Roads, http://iroads/AboutUs/KeepingWAMoving/Pages/default.aspx, accessed 21 April 2015.

NHTSA (US National Highway Traffic Safety Administration) (2012), "New DOT Research Shows Drivers Support Connected Vehicle Technology, Appreciate Potential Safety Benefit", www.nhtsa.gov/About+NHTSA/Press+Releases/2012/, accessed 22 May 2012.

NHTSA (2013), "U.S. Department of Transportation Releases Policy on Automated Vehicle Development", www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development, accessed 12 November 2014.

NHTSA (2014a), "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application", DOT HS 812 014, www.nhtsa.gov/mwg-internal/, accessed 29 April 2015.

NHTSA (2014b), "U.S. Department of Transportation Issues Advance Notice of Proposed Rulemaking to Begin Implementation of Vehicle-to-Vehicle Communications Technology", www.nhtsa.gov/About+NHTSA/Press+Releases/2014/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications, accessed 29 April 2015.

NTC (Australian National Transport Commission) (2013), "Cooperative Intelligent Transport Systems Final Policy Paper", NTC, Melbourne.

PIARC (The World Road Association) (2004), ITS Handbook, 2nd edn, Route 2 Market Ltd, Kent, p235.

PTV (Public Transport Victoria) (n.d.), "Dedicated Short Range Communications for Safer Railway Crossings", http://cms.corp.ptv.vic.gov.au/projects/railway-crossings/dedicated-short-range-communications-for-safer-railway-crossings/, accessed 17 April 2015.

Rand Corporation (2009), "Liability and Regulation of Autonomous Vehicle Technologies", report UCB-ITS-PRR-2009-28 prepared for California PATH Program, Institute of Transport Studies, University of California, Berkeley, www.rand.0rg/pubs/external_publications/EP20090427.html, accessed 29 April 2015.

SCOTI (Standing Council on Transport and Infrastructure) (2012), "Policy Framework for Intelligent Transport Systems in Australia", www.infrastructure.gov.au/transport/its/files/ITS_Framework.pdf, accessed 17 April 2015.

Suzuki, S., F, Kanazawa and T. Tsukiji (2014), "Towards Safer and More Efficient Road Traffic with Existing Road Networks and Cooperative ITS Service – Case if 'ITS Spot Service' in Japan", www.nilim.go.jp/lab/qcg/english/3paper/pdf/2014_5_2_ITS%20NZ.pdf, accessed 29 April 2015.

TCA (Transport Certification Australia) (2015), "C-ITS: Informing Decision Makers", report for TCA members, Main Roads' internal document management system TRIM D15#144364, accessed 7 April 2015.

TfNSW (Transport for New South Wales) (2014), "Smart Rest Areas", http://roadsafety.transport.nsw.gov.au/aboutthecentre/research/roadsafetytechnology/cits/smartrestareas.html, accessed 16 April 2015.

USDOT (United States Department of Transport) (2014a), "National Connected Vehicle Field Infrastructure Footprint Analysis Final Report", www.its.dot.gov, accessed 29 April 2015.

USDOT (2014b), "Harmonisation of International Standards and Architecture around the Vehicle Platform", www.its.dot.dot.gov/connected_vehicle/international_research.htm, accessed 16 April 2015.

USDOT (2014c) "Connected Vehicles Pilots Deployment Program", http://www.its.dot.gov/pilots/cv_pilot_plan.htm accessed 28 April 2015

Van Wees, K. and K Brookhuis (2005), "Product Liability for ADAS: Legal and Human Factors Perspectives", European Journal of Transport and Infrastructure Research, Vol. 5, No. 4, www.ejtir.tbm.tudelft.nl/issues/2005_04/pdf/2005_04_08.pdf, accessed 18 October 2012.

Verweij, F., N Hoose, S Sondeijker, M Kuiken, J Pommer and W Savenije (2010), "Guidelines for Policy Makers: Policy Challenges on the Way to Deployment of CVIS", www.cvisproject.org/download/Deliverables/, accessed 18 October 2012.

WA (Western Australia) Government (2013), "Every WA School Zone to Light Up for Safety" www.mediastatements.wa.gov.au/pages/StatementDetails.aspx?listName=StatementsBarnett&StatId=7215, accessed on 28 April 2015.

Wall, J (2013), "The CITI Project: Building Australia's First Cooperative Intelligent Transport System Test Facility for Safety Application", Proceedings of the 2013 Australasian Road Safety Research, Policing & Education Conference, 28th – 30th August, Brisbane.

Wikipedia (2015), "Connected Car", Wikipedia, http://en.wikipedia.org/wiki/Connected_car, accessed 2 April 2015.

Wired (2014), "Tesla's Over-the-Air Fix: Best Example Yet of the Internet of Things?", www.wired.com/2014/02/teslas-air-fix-best-example-yet-internet-things/, accessed 10 April 2015.

Zabrieszach, D. (c.2013), "ITS Activity in Australia", report to ISO TC 204 WG 9 meeting on 15 & 16 April 2013, www.its-australia.com.au/wp-content/uploads/ITS-Activity-in-Australia-April-2013-DZ.pdf, accessed 7 April 2015.

Appendix A – Glossary of terms

Acronym (if used)	Term	Description
4G	Fourth-generation wireless	Fourth generation mobile phone technology that will supersede third generation (3G)
5G	Fifth-generation wireless	Fifth generation mobile phone technology that will supersede fourth generation (4G). Will provide better speed and coverage than the current 4G.
	5.9 GHz band	Refers to the 75 MHz of spectrum between 5.850 – 5.925 GHz band of radio frequencies intended for use by DSRC for V2X communications involving specifically moving objects like vehicles.
AAMI	Australian Associated Motor Insurance Limited	Car insurance and home insurance provider, trading as AAMI.
AASHTO	American Association of State Highway and Transportation Officials	
ACC	Adaptive Cruise Control	An intelligent cruise control system that adapts the vehicle's speed to the prevailing traffic environment, using radar and/or other sensors to detect any slower moving vehicles in the path.
ACMA	Australian Communication and Media Authority	Australia's regulator for broadcasting, the Internet, radio-communications and telecommunications.
ADAS	Advanced Driver Assistance Systems	A general term for technology developed to automate, adapt or enhance vehicle systems to improve safety and better driving, and include features such as ACC and AEB.
ADR	Australian Design Rules	Australian national design standards for vehicle safety, anti-theft and emissions, which are generally performance based and covering issues such as occupant protection, structure, lighting, noise, engine exhaust emissions, braking and a range of miscellaneous items.
AEB	Autonomous Emergency Braking or Auto Emergency Braking	A system designed to intervene in critical situations by identifying potential hazards ahead of the vehicle by, in most cases, using sensors such as radar or lidar, and in combination with information about the vehicle's own speed and trajectory, to avoid the impact by warning the driver or applying brakes if no action is taken by the driver.
AUD	Australian Dollars	
AutoCRC	Automotive Cooperative Research Centre	Australian cooperative research centre established in 2005 to develop new technologies in the Australian automotive industry.
	Austroads	Austroads is an organisation comprising the road and traffic authorities of the six Australian States and two Territories, the Commonwealth Department of Infrastructure and Regional Development, the Australian Local Government Association and New Zealand Transport Agency to promote improved Australian and New Zealand transport outcomes and other things.
AV	Automated Vehicle	A vehicle where some aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input.
BDTi	Berkeley Design Technology Inc	Has founded and is leading the Embedded Vision Alliance
BSM	Basic Safety Message	The core dataset transmitted by the Connected Vehicle (vehicle size, position, speed, acceleration, brake system status) and transmitted approximately 10x per second. A secondary set is available depending upon events (e.g. ABS activated) transmitted less frequently.

C2V	Cloud-to-Vehicle or Centre-to-Vehicle	Transmission of information from the cloud or control centre to vehicles.
C2X	Cloud-to-Anything or Centre-to-Anything	Transmission of information from the cloud or a control centre to anything (such as vehicles, roadside units or nomadic devices)
CACC	Cooperative Adaptive Cruise Control	A cruise control system with the lead vehicle broadcasting location, heading and speed, and the CACC-enabled following vehicles automatically adjusting speed, acceleration and following distance, to coordinate the movements of a vehicle platoon to reduce headways between vehicles.
CAM	Cooperative Awareness Message	These messages provide information of presence, positions as well as basic status of communicating ITS stations to neighbouring ITS stations that are located within a single hop distance. All ITS stations shall be able to generate, send and receive CAMs, as long as they participate in V2X networks.
CC	Control Centre	Any control centre such as a traffic control centre communicating with vehicles or roadside infrastructure.
	(The) Cloud	Network of internet servers, some of which are specialised for storage while others us their computing power to run applications called web applications.
CCSM	Cooperative Credential Management System	Variation on the more generic Security Credential Management System, which serves as the core ICT system in a PKI implementation.
CEN	French: Comité Européen de Normalisation	European Committee for Standardisation
CITI	Cooperative Intelligent Transport Initiative	A trial of C-ITS technology along a section of freight corridor connecting Hume Hwy to Port Kembla south of Sydney.
C-ITS	Cooperative ITS	ITS platform that can be applied to vehicles and roadside infrastructure to enable direct two-way communication.
	Compass4D	A three-year EU co-funded pilot project to deploy C-ITS in a corridor connecting seven cities spreading across Europe
COOPERS	Cooperative Systems for Intelligent Road Safety	EU funded project aiming to address safety and road capacity using sensing and real-time networking technologies.
CTI	Centre for Technology Infusion	A research and innovation centre at the La Trobe University focusing on micro/nanotechnologies, and information and communication technologies.
CV	Connected Vehicle	Any 'smart vehicle' with wireless connectivity to the Internet, local network or the Cloud, other vehicles, personal communication devices, roadside infrastructure or control centres for real-time communication or exchange of data.
CVI-UTC	Connected Vehicle/Infrastructure – University Transportation Centre at University of Virginia	University research centre focusing on connected vehicle and infrastructure technologies, based in University of Virginia.
CVIS	Cooperative Vehicle-Infrastructure Systems	European research & development project aiming to design, develop and test the technologies needed for V2V and V2I communications.
CVRIA	Connected Vehicles Reference Implementation Architecture	A set of system architecture views that describe the functions, physical and logical interfaces, enterprise/institutional relationships, and communication protocol dependencies with the connected vehicle environment. It defines functionality and information exchanges needed to provide Connected Vehicle applications.
DAB	Digital Audio Broadcasting	Digital radio technology for broadcasting

	Day-one Applications	Those C-ITS applications that are proposed to be the first to be deployed.
DENM	Decentralised Environmental Notification Message	A DENM transmission is mainly used by a cooperative road hazard warning application to provide information about a specific driving environment event or traffic event to other ITS stations.
DIRD	Department of Infrastructure and Regional Development (Australian Commonwealth department)	
DSRC	Dedicated Short Range Communications	Wireless communication technology for transmission of information between moving vehicles (V2V) and transportation infrastructure (V2I).
EC	European Commission	Is one of the main institutions of the European Union and responsible for drafting new European laws, and managing day-today- business of implementing EU policies and funds.
EDB or EDFB	Electronic Brake-force Distribution	An sutomobile brake technology that automatically varies the amount of force applied to each of a vehicle's brakes, based on road conditions, speed, loading etc.
ERTICO	European Road Transport Telematics Implementation Co-ordination Organisation	Europe's ITS organisation with about 100 partners
ESC	Electronic Stability Control	A system designed to help drivers to avoid crashes by detecting and reducing skidding or loss traction as a result of over-steering, by using computer-controlled technology to apply individual brakes and increase stability.
ESL	Electronic Speed Limit (sign)	A sign which electronically displays the applicable speed limit.
ETSI	European Telecommunication Standards Institute	
ETC	Electronic Toll Collection	Means of electronically collecting tolls using electronic tags (transponders) in vehicles, wireless communication, roadside sensors and back-office systems, without any need for the driver to stop the vehicle.
EU	European Union	A politico-economic union of 28 member states that are located primarily in Europe, founded in 1993.
EVP	Emergency Vehicle Pre-emption	A system that enables emergency response vehicles request priority through equipped traffic signals.
FM	Frequency Modulation	Encoding of information in a carrier wave by varying the frequency of the wave.
FRAME		European FRAMEwork ITS Architecture
FSS	Fixed Satellite Service	A radio-communication service between earth stations at given points when one or more satellites are used to provide broadcast feeds to television stations, radio stations and broadcasts networks. Also transmits information for telephony, telecommunications and data communications.
GENIVI		An industry alliance committed to driving the broad adoption of in-vehicle infotainment software.
GLONASS	GLObalnaya NAvigatsionnaya Sputnikovaya Sistema	Russian Global Navigation Satellite System
GM	General Motors	Commonly known as GM, is an American multinational auto manufacturer headquartered in Detroit.

GNSS	Global Navigation Satellite System	Generic term for satellite navigation systems that provides autonomous geo-spatial positioning with global coverage and includes GPS, GLONASS, Galileo and Beidou.
GPS	Global Positioning System	Satellite-based radio navigation system developed by the US Defence, which provides geo-spatial positioning information including location, time and velocity in all weather conditions, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.
GSMA	Groupe Speciale Mobile (GSM) Association	Association representing the interests of mobile operators worldwide, including handset and device makers, software companies, equipment providers and Internet companies.
HMI	Human-Machine Interface	The user interface in a manufacturing or process control system, providing graphics-based visualisation of a control or monitoring system.
HTG	Harmonisation Task Group	These are formed for joint standardisation of cooperative systems, as part of the EU-US cooperation on ITS.
Hz	Hertz	Unit of frequency in SI (International System of Units). One cycle per second = 1 Hz
HUD	Heads Up Display	Transparent display that presents data without requiring users to look away from their usual viewpoints.
I2V	Roadside Infrastructure-to-Vehicle	Transmission of information from the road infrastructure to vehicles to enable a variety of safety, mobility and environmental applications.
IAP	Intelligent Access Program	National program developed in partnership with all Australian road agencies to remotely monitor where, when and how heavy vehicles are being operated on the road network by using satellite tracking and wireless communication technology.
IEEE	Institute of Electrical and Electronics Engineers	Professional association of electrical and electronics originated in the US but now a global institution. In addition to IEEE's electrical and electronics core, its membership has long been composed of engineers, scientists, and allied professionals including computer scientists, software developers, information technology professionals, physicists, medical doctors and many others.
iOS		Mobile operating system developed by Apple Inc. exclusively for Apple hardware including iPhone, iPad and iPod touch.
ISA	Intelligent Speed Adaptation	An advanced system that assist drivers to stick to the speed limit, by enabling the vehicle to know its location and the speed limit at that location through a GPS link to a speed zone database.
ISO	International Standards Organisation	Also known as International Organisation for Standardisation, ISO is an independent, non-government organisation, which is the world's largest developer of voluntary international standards.
ITS	Intelligent Transport Systems (ITS)	Comprise a range of communications, electronics and computer technologies used to improve transport services. These include: systems that collect real-time traffic data and transmit information to the public via variable message signs; ramp signals and dynamic lane control signs to improve traffic flows on freeways; and coordinated traffic signals that are dynamically adjusted in response to traffic conditions.
LAN	Local Area Network	Group of computers and associated devices that share a common communications line or wireless link to a server, typically within a small geographic area such as a home, school, computer laboratory or office building.

LCD	Liquid Crystal Display	Flat panel display that uses the light modulating properties of liquid crystals to produce images.
Lidar or LIDAR	Light Detection and Ranging	Method of using a narrow beam to transmit infrared light pulses to a target for the purpose of computing the distance to the target by measuring the elapsed time of the light beam to reach the target and return.
LTE Direct	Long Term Evolution - Direct	Wireless technology with a range of up to 500 metres
LTE-U	Long Term Evolution - Unlicensed	Is a proposal for the use of 4G LTE radio communication technology in unlicensed spectrum such as 5 GHz band.
LUMS	Lane Use Management System	A panel of electronic signs and the associated control system used to allocate and manage lane use across a freeway indicating the status of the lanes to road users including lane open, diversion or lane closed.
NHTSA	National Highway Traffic Safety Administration	A US federal executive agency focussing on safety in transport, including writing and enforcing Federal Motor Vehicle Safety Standards.
NITSA	National ITS Architecture	A common framework for planning, defining and integrating ITS adopted by a country.
NSW	New South Wales	The State of New South Wales in Australia
NTC	National Transport Commission	Established in 2003, NTC is responsible for developing, monitoring and maintaining uniform or nationally consistent regulatory and operational reforms relating to road, rail and intermodal transport in Australia.
NTCIP	National Transportation Communications for ITS Protocol	Family of standards designed to achieve interoperability and interchangeability between computers and electronic traffic control equipment from different manufacturers.
OEM	Original Equipment Manufacturers	Entity that originally manufactures an item that may be branded and sold by others. In the CV environment it is commonly used to refer to automobile manufacturers.
PATH (or California PATH)	Partners for Advanced Transportation Technology	A research & development program of the University of California in Berkeley in ITS including CVs and AVs, established in 1986.
PIA	Privacy Impact Assessment	Systematic assessment of a project, which identifies the impact that the project might have on the privacy of individuals, and sets out recommendations for managing, minimising or eliminating that impact.
PIARC	Permanent International Association of Road Congresses	Former name of the World Road Association
PKI	Public Key Infrastructure	Set of hardware, software, people, policies and procedures needed to enable users of the Internet and other public networks to engage in secure communication, data exchange and money exchange through cryptographic key pairs provided by a certificate authority.
PTV	Public Transport Victoria	Statutory authority that manages Victoria's train, tram and bus services.
QNX		Mobile operating system that was originally developed for embedded systems.
R&D	Research & Development	
RIM	Research in Motion	Canadian telecommunications and wireless equipment company best known as the developer of the Blackberry brand of smartphones and tablets.

RSU	Roadside Unit	Connected device operating from a fixed position (permanent installation or equipment brought on site temporarily) used to transmit or receive messages from another device on a vehicle or in the roadside.
SAE	Society of Automotive Engineers	Global association of engineers and related technical experts in aerospace, automotive and commercial vehicle industries.
SAFESPOT		Integrated research project involving dynamic cooperative networks, where vehicles and roadside infrastructure communicate to share information, and co-funded by the European Commission Information Society Technologies under the 6th Framework Program.
SBAS	Space Based Augmentation System	System that supports wide-area or regional augmentation through the use of additional satellite-broadcast messages and comprising of multiple ground stations located at accurately surveyed points.
SCATS	Sydney Coordinated Adaptive Traffic System	Adaptive urban traffic management system that synchronises traffic signals to optimise traffic flow across a whole city, region or corridor.
SCMS	Security Credential Management System	A public key infrastructure approach to security involving the management of digital certificates that are used to sign and authenticate messages between vehicles, equipment and other points of connection.
SCOOP@F		A project implemented by the Ministry of Sustainable Development, France, for test deployment of C-ITS.
SCOTI	Standing Council on Transport and Infrastructure	Predecessor to Transport and Infrastructure Council (SCOTI was replaced by TIC in December 2013).
SIM	Subscriber Identity Module	Smart card that stores data such as user identity, location, phone number, network utilisation data, personal security keys, contact lists and stored text messages, for GSM cellular phones.
SPaT	Signal Phase and Timing	Message type that describes the current state of a traffic signal system including phases and relates this to specific lanes/manoeuvres at the intersection.
STREAMS		ITS control system developed by Transmax.
SUNA		A real-time traffic information system for GPS devices developed by Intelematics Australia.
TCA	Transport Certification Australia	National body responsible for providing assurance in the use of telematics and related intelligent technologies.
TfNSW	Transport for New South Wales	Agency of the NSW Government that formulates and implements transport policy, and manage the transport services in NSW.
TIC	Transport and Infrastructure Council	A Council of Australian Commonwealth, State and Territory and New Zealand Ministers with responsibility for transport and infrastructure as well as Australian Local Government Association, to focus on nationally significant reforms.
TISOC	Transport and Infrastructure Senior Officials' Committee	Committee of senior officials providing advice, guidance and assistance to SCOTI (now Transport and Infrastructure Council).
TS	Technical Standard	
TSP	Transit Signal Priority	Process of giving priority for transit vehicles by reducing dwell time at equipped traffic signals by holding green lights longer or shortening red lights.
UC	Use Case	Used in software and systems engineering to define the interaction between systems and users.
UMTRI	University of Michigan – Transportation Research Institute	